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MERAMEC RIVER, MISSOURI COMPREHENSIVE BASIN STUDY. VOLUME IV. A--ETC(U)

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MERAMEC RIVER MISSOURI

COMPREHENSIVE BASIN STUDY

VOLUME IV

APPENDIX C – HYDROLOGY

APPENDIX D – GEOLOGY, SOILS, AND MATERIALS

U. S. ARMY ENGINEER DISTRICT, ST LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

JANUARY 1964

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COMPREHENSIVE REPORT

6 **MERAMEC RIVER, [redacted]**
MISSOURI

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APPENDIX C

HYDROLOGY

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TABLE OF CONTENTS

TABLES

PLATES

COMPREHENSIVE REPORT
MERAMEC RIVER BASIN, MISSOURI

APPENDIX C

HYDROLOGY

SECTION I - GENERAL

1. SCOPE

This appendix contains detailed hydrologic, hydraulic, and water resource data pertinent to formulation of the comprehensive plan of improvement for the Meramec River Basin and provides a basis for statements relating to the above subject matter that are presented in other sections of this report. A detailed analysis is presented in this appendix concerning all hydrologic aspects of water problems in the basin, including floods, droughts, and similar hydrologic considerations. The magnitude and frequency of floods are developed, stream flow data are presented, and yields are estimated. The demand for water supply is given for all uses, partially in this appendix and partially in other appendices, and evaluations are made as to how these needs can be met from projects considered in connection with this study. Hydrologic data developed herein on floods with and without various projects have been used as a basis for evaluating project flood control benefits. The hydrologic and hydraulic data presented herein have been used in the project formulation presented elsewhere in this report.

2. DESCRIPTION OF BASIN

The Meramec River Basin lies in the southeast quarter of the State of Missouri, approximately between 37°30' and 38°35' north latitude and 90°15' and 91°45' west longitude. The basin is bounded on the north by the Missouri River Basin; on the east by the Mississippi River; on the south by the St. Francis, Black, and Current Rivers; and on the west by the Gasconade River Basin. The drainage area of the entire watershed is about 3,980 square miles. The basin resembles a somewhat irregular rectangle with a median length of about 65 miles; the median width is about 55 miles. The watershed comprises all or portions of 15 counties and converges toward the city of St. Louis. The drainage system consists of the Meramec River and its two principal tributaries, the Big River and the Bourbeuse River. The Meramec River rises in Dent County, flows in a northerly direction to a point near Meramec Spring, mile 168.8, then follows a general northeasterly course to the vicinity of Kirkwood, near mile 19.0, where it turns toward the southeast to join the Mississippi River about 12 miles south of St. Louis. The Big River in general parallels the eastern boundary of the watershed, rising in the northern part of Iron County and joining the Meramec River at mile 37.5, about 3 miles south of Eureka, mile 34.6.

The Bourbeuse River has its source in Phelps County and follows a course generally parallel to the northern boundary of the basin, entering the Meramec River at mile 64.8. The drainage areas of the Big and Bourbeuse Rivers are about 968 and 848 square miles, respectively. The Meramec Basin lies within the foothills of the Ozarks, most of which are rugged and generally covered with timber. Even though streambed slopes are relatively steep, the bed is generally stable, being composed chiefly of rock and gravel. The Meramec, Big, and Bourbeuse Rivers have falls of 1,025, 970, and 740 feet in their respective lengths of 220, 137, and 145 miles. A map of the basin is shown on PLATE C-1.

3. CLIMATOLOGY

The climatology of the Meramec River Basin is of interest in this report with regard to its effect on floods, droughts, and availability of water for all uses. The Meramec River Basin has a climate of the interior continental type in which occur large temperature ranges in the daily, monthly, and seasonal values. The air masses that generally influence the climate move predominantly from the southwest frequently bringing the moisture-laden air from the Gulf of Mexico. However, it is the same southwesterly flow of air which brings in the hot dry air from the desert southwest that results in drought conditions at other times. Frequently in the winter months, cold Canadian air masses dip down and bring arctic air into the basin. The average annual temperature is about 57° Fahrenheit, and temperatures as low as -33° and as high as 115° Fahrenheit have been recorded in the basin. During the summer months, the basin is subject to showers and thunderstorms, as well as frontal storms of heavy rainfall over a wide area for several days' duration. Summer rainfall is considerably greater than precipitation during the winter months. Following paragraphs discuss those elements of climate mentioned above with supporting data in the form of plates and tables.

4. TEMPERATURE

The temperature regimen of the Meramec Basin is classed as moderate. While the average temperature is about 57° Fahrenheit, short periods of extremely cold weather are experienced in the winter months and, likewise, short periods of extreme heat occur during the summer. TABLE C-1 presents a summary of monthly and annual long-term mean temperatures for key stations within and near the basin.

5. STORMS

Severe local and heavy general rainstorms of several days' duration are not uncommon in the basin. The notable storms of record,

which have been responsible for the major floods in the Meramec Basin, have been of the general type, although rather severe local flooding has resulted from thunderstorm activity. Protracted wet periods, lasting several months, have been experienced, resulting in a series of small floods with a large combined volume of runoff. Description of the individual storm will be given in conjunction with description of flood in another section of this appendix.

6. DROUGHTS

The general classification of the Meramec River Basin is humid. It is extremely difficult to define a drought in other than very general terms. In a humid region, drought conditions could be said to exist when vegetation growing under natural conditions defoliates out of season and crops fail to mature due to lack of rainfall, or when precipitation is insufficient to meet the needs of established human activities. Any more specific definition would be extremely difficult because of many other variable factors, such as temperature, wind, soil conditions, evaporation, and the stage reached in the plant growth cycle. In U. S. Geological Survey Water Supply Papers 680 and 820, J. C. Hoyt in a study of droughts concluded that in humid states serious drought effects do not result unless the annual precipitation has a deficiency of 15 percent or more of the mean. Studies presented in a later section indicate a number of periods with much greater annual deficiency than this.

SECTION II - PRECIPITATION

7. SOURCE OF DATA

The U. S. Weather Bureau is the only agency engaged in the collection and compilation of precipitation data within the Meramec River Basin on a continuing daily basis. The Corps of Engineers has compiled unofficial records for some notable storms. The principal source of rainfall data used in the preparation of this study was the U. S. Weather Bureau Climatological Bulletins. A total of 41 stations presently active and maintained by the Bureau was used in this study. The period of record ranged from 2 to 124 years. Locations and types of stations are shown on PLATE C-2.

8. ANNUAL PRECIPITATION

The average annual precipitation for the basin, as computed from 12 key stations with periods of record ranging from 30 years to 124 years, is about 39 inches. The range is from 35.44 to 42.51 inches. TABLE C-2 lists the rainfall stations with periods of record in excess of 30 years, together with long-term means for stations where such records are available.

9. SEASONAL PRECIPITATION

The seasonal distribution of rainfall is indicated on TABLE C-2. The normal growing season in the basin is from mid-April to mid-October, and about 23 inches of rain, or 59 percent of the annual total, normally falls in this period. Precipitation is fairly well distributed throughout the year, with the highest average occurring during the months of April, May, and June, and the lowest during the months of December, January, and February. Frequent autumn storms bring the rainfall average for August, September, and October relatively high. The greatest deviation from the mean probably occurs during the months of July and August, with the possibility of extremely heavy rainfall or extreme drought conditions.

10. ANNUAL SNOWFALL

Snowfall is usually limited to the period from October to April and seldom covers the ground for long periods. The average annual snowfall is light, amounting to about 16 inches, and is not considered to be a factor in flooding.

11. RAINFALL INTENSITY

While rather intense local storms have occurred frequently throughout the basin, official records are lacking. However, TABLE C-3

indicates record intensities experienced at St. Louis, Missouri, just to the north and east of the Meramec River Basin.

12. STORMS OF RECORD

General storms with heavy rainfall extending for several days' duration have produced the more notable storms over the basin. Since it is reasonable to assume that major floods result from major storms, it appears that major storms occurred in 1913, 1915, 1916, 1919, 1942, 1945, 1950, and 1957, the years of major floods. Detailed rainfall records are not available for the years 1913, 1916, and 1919. The following tabulation shows storms of record for which data are available, and PLATE C-3 shows a sample isohyetal map for a major storm of record. Storms are discussed later in conjunction with floods produced.

Storms of record

Storm period	Average precipitation over basin (inches)
18-20 August 1915	8.22
26-29 December 1942	4.93
5-11 June 1945	6.12
1- 6 January 1950	4.10
26 June-2 July 1957	5.06

13. SUBNORMAL PRECIPITATION

Despite the fact that the Meramec River Basin lies in a region that is considered to have reasonably adequate precipitation under normal conditions, it does experience relatively long periods of deficient rainfall. The best picture of this condition is probably indicated in study of deficient runoff which is presented in a later section of this report dealing with runoff.

SECTION III - RUNOFF

14. RUNOFF DATA

The collection and tabulation of surface and groundwater data within the Meramec River Basin are primarily a responsibility of the U. S. Geological Survey. These data, published in U. S. Water Supply Papers, were the primary source of information for development of the basin studies. The Corps of Engineers made a few scattered discharge measurements within the basin during high water periods. Additional data on river stages were obtained from U. S. Weather Bureau's annual publications, "Daily River Stages". These, in general, were the sole sources of runoff data within the basin.

15. RUNOFF IN GENERAL

The Meramec River Basin above Eureka lies entirely within the foothills of the Ozarks, which are generally rugged and covered with timber. The Meramec River streambed, together with those of the Big and Bourbeuse Rivers, in general, is composed of rock, gravel, and sand. The numerous tributary streams, both large and small, have rather steep slopes that allow rapid runoff to the main streams. The ratio of runoff to rainfall is high throughout the basin. Infiltration is relatively slow in these soils, resulting in rapid and substantial runoff from short periods of intense rainfall. Extended periods of rainfall saturate the shallow soil cover, permitting very high percentages of runoff.

16. RIVER STAGE AND STREAM GAGING RECORDS

Throughout the period of record, 20 gages have been operated within the basin and at the present time 13 are still active. Of the 13 presently active gages, 10 are recording gages, one is rated to permit conversion from stage to discharge, and two are for river stage only. The period of record and type of river stage and stream gaging stations within the basin are given on PLATE C-4. Locations are shown on PLATE C-2.

17. MONTHLY RUNOFF

Mean monthly flows for the period of record for the Meramec River at Steelville and Eureka, the Big River at Byrnesville, and the Bourbeuse River at Union are shown graphically on PLATE C-5. The monthly runoff data for the Meramec River at Eureka for the period of record are shown on TABLE C-4. The greatest average monthly runoff is 6,026 c.f.s., occurring in April, and the lowest is 1,114 c.f.s., occurring in September. The maximum mean monthly flow

of record is 22,600 c.f.s. in April 1927, and the minimum of 236 c.f.s. occurred in October 1956. The average monthly runoff for the period of record is 3,096 c.f.s.

18. RUNOFF EXTREMES AND MEANS

Extremes of runoff at the principal gages in the Meramec River Basin are shown on TABLE C-5. The greatest known discharge within the basin occurred at Eureka on 22 August 1915 and amounted to 175,000 c.f.s. The lowest flow recorded at any of the principal gages was 11 c.f.s. at Union on 10 October 1956.

19. MAJOR FLOODS OF RECORD

The streams in the Meramec Basin frequently overflow their banks. The major floods, in general, have been caused by excessive rains which were general over the entire watershed, rather than by intense local storms. Major floods of record occurred in 1904, 1913, 1915, 1916, 1919, 1942, 1945, 1950, and 1957. Records are not available for 1904, 1913, 1916, and 1919, but descriptions of major storms and resulting floods are given in following paragraphs.

20. AUGUST 1915 FLOOD

a. Rainfall. This flood was produced by an average rainfall of 8.22 inches over the entire Meramec Basin during 18-20 August. Total rainfall during the months of May to August, inclusive, was 28.28 inches, which was not only 10.65 inches above the seasonal normal for the State, but was 72 percent of the average yearly total. The period of excessive rains came to an end with the passage of the West Indian storm of 29 August, which caused heavy damage in the eastern half of Missouri from the southern border to north of St. Louis. In the 24 hours preceding 20 August, 4.35 inches of rain fell at Rolla and 5.17 inches at Gano, both in the upper reaches of the watershed; at Oakfield, about 4 miles north of Pacific, 8.18 inches of rainfall was recorded. At St. Louis, about 10 miles northeast of the basin, on 20 August, midnight to midnight, 8.20 inches was recorded. During August, rains occurred almost daily and, during the latter part of the month, were torrential in the eastern part of the Ozark Plateau.

b. Flood stages. The resulting flood was the greatest known in the Meramec Basin. It reached a crest on 22 August, equivalent to 40.2 feet on the present Eureka gage, as determined from high water marks. Other crest stages on the Meramec River during the August 1915 flood were: 26.5 feet at Steelville on 20 August; 33.5 feet at Sullivan on 21 August; 30.82 at Pacific on 22 August; and 37.85 at Valley Park on 22 August. By the slope-area method, the U. S. Geological

Survey estimated the peak discharge at Eureka to be 175,000 c.f.s., the average runoff from the watershed above Eureka being 5.32 inches. The valley of the Meramec was completely inundated, resulting in total loss of crops and severe property damage, especially at Valley Park, the place of greatest inundation. As far as could be ascertained, no lives were lost.

21. DECEMBER 1942 FLOOD

a. Rainfall. December 1942 was a cold, wet, cloudy, and disagreeable month with an unusual amount of snow. Temperatures were such that alternating periods of freezing and thawing left the ground either frozen or muddy. On 22 December, a warming trend set in, which culminated in temperatures reaching highs of middle sixties to middle seventies throughout the Meramec Basin on 28 December. Precipitation averaged above normal throughout the State, and at Salem and Rolla the rainfall for the month was 5.96 and 3.68 inches above normal, respectively. During the period 26-29 December, rainfall totaled 2.60 inches at Valley Park, 3.85 at Pacific, 4.00 at Richwoods, 4.05 at Gerald, 4.08 at Belleview, 4.54 at Union, 4.70 at Rolla, 5.22 at Owensville, 5.37 at Meramec State Park, and 7.02 at Salem. The weighted average rainfall for the basin was 4.93 inches.

b. Flood stages. This heavy rainfall of 26-29 December resulted in unusually high water and flood conditions. At most stations, crest stages were the highest of record for December. Monetary losses were considerably lessened because of the time of the year the flood occurred. At Eureka, the crest stage reached 31.78 feet and discharge reached 69,600 on 30 December. Other crest stages in the basin were: 22.0 feet at Steelville on 28 December, 19.00 at Union on 29 December, and 22.0 at Byrnesville on 28 December. Runoff from the storm from watershed above Eureka was about 2.93 inches.

22. JUNE 1945 FLOOD

a. Rainfall. The storm producing this flood, the largest since 1915, occurred from 5 June through 11 June and was most intense in the upper reaches of the basin, centering around Belleview where 10.84 inches of rain fell, with 7.93 inches and 8.23 inches at Steelville and Cuba in the center of the basin above Eureka. Other amounts were: 2.53 inches at Union, 2.39 at Moselle, 1.85 at Pacific, and 2.03 at Valley Park. About 30 miles southwest of Rolla, a very heavy and intense rain of cloudburst proportions fell locally at Newburg, Phelps County, on the afternoon of 8 June, resulting in a flash flood which drowned five persons and caused property damage estimated at $277,000. Estimates of the torrential downpour vary from 5 to 8 inches.

b. Flood stages. The 5-month period preceding the flood was the wettest in the State for the previous 58 years. During the first 6 months of the year, there was as much or more precipitation as normally occurs in the whole year, particularly in the southern part of the State. The average rainfall over the watershed above Eureka for the storm period was 6.12 inches. The crest of this flood was 2.2 feet below the 1915 flood crest at Steelville, 1.5 feet below Sullivan, 3.3 feet below Eureka, and 4.85 feet below Valley Park. The crest occurred at Eureka at 5:00 AM, 11 June, with a maximum stage of 36.94 feet and a peak discharge of 120,000 c.f.s., the average runoff from the watershed above Eureka being 3.71 inches. The lowlands of the Meramec River were inundated, resulting in total loss of crops and extremely heavy property damage in the lower part of the valley around Valley Park and Times Beach.

23. JANUARY 1950 FLOOD

a. Rainfall. January 1950 was an extremely mild and wet month. The outstanding features were the heavy and excessive rainfall in the southeastern section and the unusually high daily temperatures for January. The mean temperature was 35.7°, or 4.8° above normal. The average precipitation, 5.52 inches, was 3.21 inches in excess of the normal. Average precipitation for the month in the southeastern section of the State was 10.41 inches, or 7.18 inches above normal. At three stations in the Meramec River watershed, long-term records indicate the following monthly rainfall and departure from normal: Rolla, 6.48 inches or 4.02 inches above normal; Salem, 7.33 inches or 4.61 inches above normal; and Union, 5.47 inches or 3.15 inches above normal. For the period 1-6 January, rainfall in the basin ranged from 3.10 inches at Vichy to 4.98 inches at Cook Station and was distributed throughout the basin relatively evenly.

b. Flood stages. A large amount of precipitation in the southeast portion of the State was in the form of freezing rain and, as a result, considerable ice accumulated. In spite of the heavy icing condition, considerable flooding occurred in the basin. On the Meramec River itself, stages of 18.74, 25.5, 33.01, and 30.0 feet occurred, respectively, at Steelville, Sullivan, Eureka, and Valley Park. On the Big River, a stage of 23.91 feet was reached at DeSoto, and 25.23 feet was the peak at Byrnesville. While the flooding on the Bourbeuse River was not as severe as for the Big River and Meramec River, nevertheless, stages of 28.00 feet and approximately 19.5 feet were reached at Spring Bluff and Union, respectively. The peak flow reached at Eureka was 79,700 c.f.s., and runoff for the storm of 1-6 January equaled 2.47 inches over the basin above Eureka.

24. JUNE-JULY 1957 FLOOD

a. Rainfall. June 1957 rainfall ranged from generally heavy in the southern part of the State to much lighter in the northern sections. The June totals exceeded 10 inches over a large area west and south of St. Louis. For the State as a whole, June 1957 was the wettest June since 1951. Precipitation during June exceeded the 25-year means at almost all stations south of the Missouri River. The St. Louis vicinity received several times the long-term mean. Beginning on 26 June, a series of showers occurred over the Meramec Basin and continued until 2 July, with extremely heavy rainfall in the lower end of the Meramec River Basin on 1 July. Rainfall for the period 26 June to 2 July 1957 within the Meramec River Basin ranged from 11.74 inches at Gerald to 2.45 inches at Potosi.

b. Flood stages. The resulting flood was, principally, a downstream flood. Heavy thundershowers caused major flooding in the Valley Park area on 2-3 July. The Meramec River at this point rose to 16 feet above flood stage. It was necessary to evacuate 800 people from about 200 homes. At Steelville on the upper Meramec River, flood stage was not reached, but at Sullivan and Eureka stages of 22.61 feet and 35.77 feet, respectively, resulted. On the Bourbeuse River, a stage of 34.71 feet was reached at Spring Bluff, while that reached at Union was 24.44 feet. Resulting stages on the Big River were 27.15 feet at DeSoto and 26.41 feet at Byrnesville. The peak discharge reached at Eureka was 99,500 c.f.s., and the volume of runoff passing Eureka from this storm was equivalent to 3.13 inches of runoff over the upstream drainage area.

25. PERIODS OF SUBNORMAL RUNOFF

Subnormal runoff occurs annually within the Meramec Basin for periods of 1 to 8 months, but these periods are generally of such short duration as to cause only minor inconvenience and damage in restricted areas. Since stream flow records in the basin are not generally available prior to 1922, information on deficient runoff is confined to the 40-year period of 1922-1961. Eureka on the Meramec River, Union on the Bourbeuse River, and Byrnesville on the Big River have records of 40-year duration. Only those periods at these gaging stations, when runoff was subnormal for 12 or more consecutive months, were studied in detail. Results are shown on TABLES C-6 to C-8. Records at these three gaging stations indicate that, while each may have periods of low flow not in common with the others, they do have in common five prolonged periods of subnormal flow in the 40 years of records. These periods are 1930-31, 1933-34, 1939-41, 1952-55, and 1955-57. By far the most severe period for duration as well as accumulated deficiency was that for the 1952-55 period. Furthermore, with a break of only 1 to 2 months, this drought continued until January 1957. Flows at Eureka, Missouri, for this combined 1952-55

and 1955-57 period were only 39 percent of normal for a period of 1,737 days. This accumulated deficiency amounted to 6,315,732 acre-feet of runoff at Eureka.

26. FLOOD PROFILES

Data on peak flood stages and high water marks for the Meramec, Big, and Bourbeuse Rivers were compiled and used in defining profiles for various floods of record. Few, if any, high water marks are available for tributary streams, and those that are available are in extreme lower reaches and reflect backwater from main streams. Flood profiles for floods of record are shown on PLATES C-6 to C-8.

SECTION IV - EVAPORATION AND INFILTRATION LOSSES

27. GENERAL

The primary concern of the present study with evaporation is in the realm of water losses from reservoir surfaces. The design and operation of the reservoirs must take into account the effects of evaporation on the dependable minimum yields of proposed projects. This section presents available evaporation data and the results of a study of infiltration losses.

28. EVAPORATION

From records at Lakeside, Missouri, and Washington University, St. Louis, Missouri, the weighted average annual evaporation from evaporation pans was estimated at 52.3 inches. With a pan coefficient of 0.76, the maximum average monthly evaporation of 6.38 inches occurred in July and the minimum of 1.04 inches in December. Annual and monthly evaporation is tabulated below. These data are in reasonable agreement with information published by U. S. Weather Bureau, Technical Paper No. 37, "*Evaporation Maps for the United States*".

Weighted average annual and monthly evaporation
Meramec River Basin

Month	Weighted average evaporation pan (inches)	* Reservoir evaporation (inches)
January	1.43	1.09
February	1.70	1.30
March	3.39	2.59
April	4.97	3.80
May	6.22	4.75
June	6.77	5.17
July	8.35	6.38
August	7.12	5.44
September	5.24	4.02
October	3.65	2.79
November	2.13	1.63
December	1.36	1.04
Annual	52.33	40.00

* Pan coefficient 0.76.

29. ANNUAL WATER BALANCE

While detailed study of evapotranspiration loss was not attempted in this study, the average annual precipitation for the basin is 39 inches; and the average annual runoff at Eureka, Missouri, is 11 inches over upstream drainage area for an average annual loss of 28 inches. Due to the detailed nature of the study required, no attempt was made in the report to delineate the various losses.

30. INFILTRATION

Runoff factors and average infiltration rates were computed at each of the gaging stations with records starting in 1922 for flows which exceeded bankfull. A total of 202 "station-storm" average infiltration rates was determined. Results of this study indicate that there is no well-defined geographical subdivision of the Meramec River Basin as far as infiltration rates are concerned. However, adjustment of infiltration losses for season and for antecedent rainfall conditions was made in the study. TABLE C-9 shows over-all basin infiltration characteristics by hourly rates.

SECTION V - BASIC HYDROLOGY STUDIES

31. SCOPE OF BASIC STUDIES

The comprehensive development of water resources for a river basin requires planning with the use of certain basic information and analyses in order to evaluate properly the potential of these resources. Information referred to herein consists of basic data on physical characteristics, precipitation, runoff, evaporation, and infiltration, which were covered in preceding paragraphs of this appendix. Analyses of various combinations of these data provide the basic hydrologic means of planning in the comprehensive basinwide development of water resources. The studies required in these analyses for the Meramec River Basin are presented in subsequent paragraphs.

32. MASS CURVES

Published records of mean monthly stream flow were used as basic data in the preparation of mass curves within the Meramec River Basin. Mass curves were prepared for the stations that had 40 years of continuous record and the tabulations were prepared from actual observed flows. The standard period was 1922-1961, inclusive. A sample mass curve for the Meramec River at Steelville is shown on PLATE C-9.

33. MASS CURVES FOR CRITICAL LOW-FLOW PERIOD

Mass curves of runoff during the most critical period were developed at each of the proposed reservoir sites. Flows at the nearest downstream gaging station were adjusted by the ratio of drainage areas. By use of the theoretical flow at the site and application of pertinent evaporation losses, the flow that could be sustained throughout the critical period by use of available storage was established.

34. CURVES OF EXCESS RUNOFF

Automatic Data Processing equipment was used in the development of these curves. Daily flows at gaging stations were converted into cubic feet per second per square mile. Values of flood control release, expressed in cubic feet per second per square mile, were assumed and the daily converted flows were scanned. Those in excess of the selected release were accumulated throughout each excess period. Thus, for any location of proposed reservoir, the values of excess developed need only be multiplied by the drainage area at the proposed site to determine the storage in the flood control pool for that period.

35. CURVES OF DEFICIENT RUNOFF

A similar procedure to that described in the preceding paragraph was used in the development of these curves. However, in this case, flows less than the selected value were accumulated throughout each deficient period. In order to facilitate the economic evaluation of storage required versus releases from the various reservoirs within the Meramec River Basin, without the necessity of developing mass curves of runoff at each of the sites, sufficient selected values of flow were used to permit development of curves of flow versus deficiency at each of the principal stream gaging stations. The unit used for both selected flow and accumulated deficiency was cubic feet per second per square mile. Based on the assumption that the yield from ungaged areas is proportional to that from areas gaged downstream in a ratio of drainage areas, it is possible to go to the proper curve with a flow requirement at any reservoir site and determine the flow deficiency at that point. Since the curve expresses deficiency in cubic feet per second per square mile and because deficiency and storage required are one and the same, the storage required for a specified release during the critical low-flow record can be computed.

36. FLOW DURATION CURVES

Data taken from U. S. Geological Survey Water Supply Papers were used in the preparation of mean daily flow duration curves for the Meramec River Basin. Curves were developed for the following stations in the basin:

Eureka on the Meramec River
Sullivan on the Meramec River
Steelville on the Meramec River
Byrnesville on the Big River
DeSoto on the Big River
Union on the Bourbeuse River

Since the data used in the development of the curves were observed flows without reservoir modification, they reflect existing conditions within the basin. The flow duration curve thus developed for Steelville, Missouri, is shown on PLATE C-10.

37. FREQUENCY ANALYSES OF PEAK FLOWS

U. S. Geological Survey stream flow records for seven stations in the Meramec River Basin were used in frequency analyses. Records available for instantaneous peak flows ranged from 43 years at Union to 11 years at DeSoto. In addition, stage records at Valley Park were

available for a period of 43 years and were converted into flows by use of a rating curve so that a flow frequency curve could be developed at that location.

38. NOMENCLATURE

The item "frequency curves" refers to the cumulative frequency distribution of the logarithms of the annual peak flows based on calendar years. This curve, being representative of cumulative frequencies in descending order of magnitude, indicates the percent chance that an annual peak will be equaled or exceeded and may be designated "exceedence frequency". The terminologies "percent chance of occurrence" and "exceedence frequency" are interchangeable. The following are symbols used in the frequency analyses of peak flows:

m = Mean of logarithms of annual peak flows, log Q_m.

$\bar{s}$ = Standard deviation, which is the root-mean-square deviation of the logarithms of the annual peak flow.

$m + \bar{s}$ = Logarithms of annual peak flow with 15.9 percent exceedence frequency, log $Q(m + \bar{s})$.

Q_m = Annual peak flow in c.f.s. having 50 percent exceedence frequency.

$Q(m + \bar{s})$ = Annual peak flow in c.f.s. having 15.9 percent exceedence frequency.

The values of m and $\bar{s}$ used in the frequency generalizations are those adjusted values shown in the following tabulation under "Extended Record".

Summary of peak frequency statistics

Stream	Location	Drainage area	Period of Record Yrs.	Period of Record m	Period of Record $\bar{s}$	Extended period Yrs.	Extended period m	Extended period $\bar{s}$
Meramec	Valley Park	3,850	47	4.5780	0.3000	47	4.5780	0.3000
Meramec	Eureka	3,788	38	4.5230	0.2786	47	4.5979	0.3029
Meramec	Sullivan	1,475	38	4.2836	0.3194	47	4.3757	0.3010
Meramec	Steelville	701	37	4.1348	0.3456	47	4.2370	0.3157
Big River	Byrnesville	917	37	4.1664	0.2396	37	4.1664	0.2396
Big River	DeSoto	718	11	4.2328	0.2797	37	4.1989	0.2586
Bourbeuse	Union	808	45	4.1350	0.2240	45	4.1350	0.2240
Bourbeuse	Spring Bluff	608	16	4.1874	0.2630	45	4.2130	0.2080

39. DEVELOPMENT OF FREQUENCY CURVES FOR INDIVIDUAL STATIONS

In the initial phase of this study, frequency curves were developed comparing Hazen, extreme value, and Beard's methods. From analysis of these, it was found that the Beard method most nearly reflected conditions in the basin. Thus, the basic statistics, the mean (m), and the standard deviation ($\bar{s}$) were computed analytically for each of the individual gaging stations following the Beard method. Straight line frequency curves were drawn on log probability paper with slopes equal to the standard deviations and with the means at 50 percent probability.

40. ADJUSTMENT TO LONG-TERM RECORD

In each of the three main contributing drainage areas, one gaging station had a period of record substantially longer than other stations on the respective stream. These "base" or "long-term" stations were Valley Park on the Meramec River, Brynesville on the Big River, and Union on the Bourbeuse River. Correlation studies to be described in subsequent paragraphs made it evident that extension of record should be limited to that of the "long-term" station within the individual basins. Initially, the (m) and ($\bar{s}$) were derived for each station for the actual period of record. Another (m) and ($\bar{s}$) determination was then made for the "long-term" station, but only for the years of record of the short-term stations. This ratio of long-term (m) and ($\bar{s}$) to short-term was then applied to the period of record (m) and ($\bar{s}$) for the stations with shorter records, and synthetic "long-term" (m) and ($\bar{s}$) values resulted. Sample frequency curve and adjustment to long-term record are shown on PLATE C-11.

41. FREQUENCY ANALYSES - HIGH MEAN FLOWS

Automatic Data Processing equipment was used in determination of the highest mean flow for 1, 3, 5, 10, 15, 20, 30, 60, 90, 120, and 180 days and mean yearly flow for each calendar year. This procedure was followed at each gaging station for the respective period of record. From these statistics, frequency curves were developed for each station and each condition. The method for extension of record previously described for peak flows was not applicable here because, while peak flows for "long-term" records at "base" stations were available, daily flows were not. Sample curves are shown on PLATE C-12.

42. GENERALIZED FLOOD FREQUENCY STUDIES

Prior paragraphs have dealt with the derivation of frequency curves at gaging stations within the Meramec River Basin. The fact that a comprehensive basin study requires study of all areas, gaged and ungaged, made necessary a study of the possibility of development of generalized or regionalized frequency curves, which could be used in tributary and

headwater areas, where records are not available, with reasonable confidence in their accuracy. An attempt was first made to prepare generalized frequency curves which would be applicable to the entire Meramec River Basin. It was thought that a reasonable relationship should exist between basic $\bar{s}$, m, and m + $\bar{s}$, previously developed, and one or more of the following: drainage area, stream slope, stream length, or ratios of one to another. In all cases, on a basinwide analysis, the scattering of plotted points was so divergent as to be meaningless.

43. FINAL RESULTS OF FREQUENCY STUDY

The final decision was to develop separate generalized frequency curves for the Meramec, Big, and Bourbeuse Rivers. The 200-, 100-, 50-, 25-, 20-, 10-, 5-, and 2-year frequencies at each of the gaging stations were converted into cubic feet per second per square mile and plotted against the proper drainage areas. The slope of the lines was established from use of a minimum amount of short-term data for small areas. Sample generalized frequency curves are shown on PLATE C-13. Copies of these curves were forwarded by letter, LMLED-H, U. S. Army Engineer District, St. Louis, 6 November 1962, subject: "Meramec River Basin - Generalized Frequency Curves (Revised)", and approved by 2nd Indorsement thereto, ENGCW-EY, Office, Chief of Engineers, 28 November 1962.

44. MODIFICATION OF FLOOD FREQUENCY CURVES

A basic tool for derivation of flood control benefits attributable to specific projects is the flood frequency curve and its modification by flood control projects. Determination of the effects of a specific project or projects at downstream damage reaches is accomplished by adjustment of the frequency curves so as to indicate the reduction of peak flow brought about by operation of the projects. These adjustments were made by holding the natural frequency of a particular flood constant and plotting the modified peak discharges at the same frequency. Effects of the proposed reservoir projects on major floods of record and hypothetical basin floods were determined and plotted as reduced peak flows below the natural frequency curves. Modified frequency curves were drawn through these points using natural curve as a guide. This modification is shown on PLATE C-14.

45. FLOOD FREQUENCY ANALYSES FOR DAMAGE INTEGRATION

Annual flood peaks were analyzed following procedures outlined in Technical Memorandum, dated 13 January 1961, subject: "Hydrologic Relationships Pertaining to the Generalized Flood Hydrograph - Damage Integration (FHG), Method of Estimating Flood Damages in Agricultural Areas". Flood peaks were analyzed at four long-term stations within

the basin, and the necessary curves, charts, and graphs were developed whereby damages could be determined.

46. LOW-FLOW FREQUENCIES

With regard to agricultural and industrial operations and domestic and municipal water needs, the lowest instantaneous discharge during a given time period is not, in itself, of primary concern. The most damaging effect of low flows results from subnormal flow for a prolonged duration. Therefore, the frequency curves for low flows in the Meramec River Basin are based on the lowest mean flow for duration of 1, 3, 5, 10, 20, 30, 60, 90, 120, and 180 days. These curves are readily convertible to volume for duration-volume studies. Sample low-flow frequencies are shown on PLATE C-15.

47. DRAINAGE AREA VERSUS RIVER MILEAGE

Drainage areas as published in the U. S. Geological Survey Water Supply Papers were accepted for use at each of the gaging stations in the Meramec River Basin. As various phases of the study were reached, drainage areas were determined for (1) all principal tributaries of the three main streams, (2) at each proposed reservoir site, and (3) for a number of intermediate locations that were desirable in key areas. By making use of all such drainage areas developed, a graph of drainage area versus river mileage for each of the three main streams was derived. An example of this type of chart is shown on PLATE C-16.

48. UNIT HYDROGRAPHS

The comprehensive basin study requires a means of development of synthetic flood hydrographs of runoff from hypothetical storms over both gaged and ungaged areas. Unit hydrographs are the basic tools for accomplishing this. Unit hydrographs were derived from observed floods at existing or discontinued stream gaging stations in the basin. For ungaged areas, unit hydrographs were developed synthetically from generalized studies utilizing empirical relations of unit hydrograph features versus basin characteristics. Analysis of all available basin rainfall and runoff data was necessary in order to best develop unit hydrographs of observed floods.

49. BASIC DATA AVAILABLE FOR DERIVATION OF UNIT HYDROGRAPHS AT GAGING STATIONS

Stage and stream flow data were obtained from U. S. Geological Survey records. Additional stage and precipitation data from the U. S. Weather Bureau and Corps of Engineers records were used. Study of all available data indicated that for the period of record there

was no single basinwide storm suitable for development of unit hydrographs at all gaging stations. The year 1945 was a flood year of great magnitude throughout the basin but, because of the nature of the precipitation at most gaging stations, the runoff hydrograph was a series of peaks which were difficult, if not impossible, to separate one from another. At three tributary gaging stations of short-term record, only one storm was available for analysis, but at main stem gaging stations the number of storms analyzed in order to develop an average unit hydrograph for individual stations ranged from a minimum of three at DeSoto and Spring Bluff to a maximum of eight at Byrnesville.

50. FLOOD CRITERIA FOR UNIT HYDROGRAPH STUDIES

Primary requirement for selection of storms to be used in the derivation of unit hydrographs is the availability of sufficient hourly precipitation data so that time and areal distribution of precipitation can be well delineated. General criteria used in selection of storm flood periods were:

a. That the volume of flood runoff be in excess of 1 inch if possible.

b. That the hydrograph of flood runoff be a well-defined, single-peaked, well-isolated event, as free as possible from effects of antecedent or subsequent precipitation.

c. That continuous stage records be available for the period involved.

51. DEVELOPMENT OF UNIT HYDROGRAPHS

U. S. Weather Bureau Climatological Bulletins were used as a source of hourly records of precipitation. Total storm rainfall for both recording and non-recording stations was plotted on the map and isohyetals were drawn. The drainage area was subdivided by a series of Thiessen polygons defining areas which were nearest the various reporting stations. Following procedures as outlined in paragraph 16 of EM 1110-2-1405, "Flood-Hydrograph Analyses and Computations", unit hydrographs were developed for each gaging station and each storm runoff period that, in general, fulfilled the adopted criteria. From these numerous hydrographs, an average unit hydrograph was adopted for each station giving greater weight to those that more nearly approached ideal conditions. These unit hydrographs, on appropriate forms prescribed in CWI Project CWI-153, were forwarded by letter, LMLED-H, U. S. Army Engineer District, St. Louis, 29 September 1961, subject: "Request for Field Conference - Hydrology and Hydraulics - Meramec Basin Investigation", with request for field conference on 11-12 October 1961. Paragraph 5 of the minutes of said conference indicates that

derived unit hydrographs were satisfactory. Sample derivations of unit graphs are shown on PLATES C-17 and C-17A. Characteristics and ordinates of these derived unit hydrographs are tabulated in TABLE C-10.

52. SYNTHETIC UNIT HYDROGRAPHS FOR UNGAGED AREAS

The need for unit hydrographs for ungaged areas has led to development of several methods of derivation of synthetic unit hydrographs. The following methods were used to develop these synthetic unit hydrographs.

a. "Unit-Hydrograph Lag and Peak Flow Related to Basin Characteristics", by Arnold B. Taylor and Harry C. Schwarz, as presented in Transactions, American Geophysical Union, Volume 33, Number 2, dated April 1962.

b. "Synthetic Unit-Hydrographs for Small Watersheds", by Don M. Gray, as presented in Journal of the Hydraulics Division, Proceedings of the American Society of Civil Engineers, Volume 87, Number HY4, Part 1, July 1961.

c. "Synthetic Unit Graphs", by Franklin F. Snyder, Transactions, American Geophysical Union, Part 1, 1938, pages 447-454.

In order to find the method best adapted to the Meramec River Basin Study, each of the three methods was used to develop a unit hydrograph for one of the gaged areas and compared with the one for that location which was derived from observed data. Results obtained from the use of method "b" were inconclusive and considered to be unsatisfactory. Method "a" checked very well for peak flows, but appeared to have unusually long lags for small areas and unusually short lags for large areas, with the area of best agreement at about the 400-square mile range. As a result, method "c" was used in final development of synthetic unit graphs.

53. BASIN CHARACTERISTICS

In order to determine basin characteristics to be used in developing synthetic unit graphs for ungaged areas, the C_t and C_p640 values derived in the development of the natural unit hydrographs were plotted against drainage area. PLATES C-19 and C-20 show these curves. For each location where a synthetic unit hydrograph was desired, the drainage area was planimetered, length (L) was measured from U. S. Geological Survey quadrangle sheets, L_{ca} was determined by method indicated on page 11 of EM 1110-2-1405, and C_t and C_p640 values were taken from the above curves. Unit hydrographs were then developed by use of the nomograph developed by Omaha District Corps of Engineers. Sample

synthetic unit graph is shown on PLATE C-21. Characteristics and ordinates of synthetic unit hydrographs are tabulated in TABLE C-11. For locations of reservoirs at which synthetic unit hydrographs were developed see PLATE C-18.

54. STREAM FLOW ROUTING

Routing studies under natural conditions were made using the average-lag method. Automatic Data Processing equipment was used extensively in this operation. In the initial phase of the routing study, reaches of the river were limited to those between gaging stations. A preliminary estimate of flow time between stations was established by a study of peak times at the stations and measured velocities under various flow conditions. Results of this study indicated relatively short flow times in some reaches, so that it was decided to use 6-hour ordinates in the process of averaging and lagging. Within the relatively broad limits established by the preliminary study, numerous combinations of average-lag constants were applied to ordinates of a flood of record until "best-fit" was reached at downstream location. Using these constants, a routing of a second flood of record was made to verify results.

55. HEADWATER STREAM FLOW ROUTING

With the realization that routings from upstream points,as well as from tributary sources, would be necessary, the following procedure was adopted. By use of rainfall intensities and areal distribution derived in the study of unit graphs from floods of record, rainfall increments were applied to synthetic unit graphs developed at all proposed reservoir sites and at the mouths of all principal tributary streams. Wherever possible, these synthetic runoff hydrographs were checked against high water marks and adjusted if necessary. Then, following procedure identical to that for reaches between gaging stations, average-lag constants were established and verified. This procedure made necessary a further breakdown of reaches. In general, these reaches were established, on tributaries, from proposed reservoir site to mouth of stream and, on main stem, as reaches between points at which principal tributaries entered the river in question.

56. RECONSTITUTION OF FLOOD HYDROGRAPHS OF RECORD

The 1945 and 1957 flood hydrographs for each gaging station on the main streams were reconstituted by the average-lag method. The reconstituted hydrographs compare favorably with the actual observed hydrographs. Comparison of observed and routed hydrographs appears on PLATE C-22.

57. ROUTING OF MODIFIED FLOWS

The average-lag method was also used in routing of flows as modified by individual reservoirs or systems of reservoirs. Essentially the same procedure was used as under natural conditions except that reservoir inflow hydrographs were developed to determine the flood hydrographs of inflow into each reservoir. An example of the individual contributions of natural flows for the sub-areas involved is shown on TABLE C-12. For those reservoir sites classified as major sites, the flood control storage was established as 100 percent of runoff from "Standard Project Storm", and the effects of these reservoirs on downstream reaches were easily determined. However, for sites of lesser capacity, flood hydrographs were routed through reservoir storage to determine releases effective downstream.

58. FLOOD CONTROL CAPABILITY OF RESERVOIRS

As a part of the flood routing studies, a comparison was made of flood control capabilities of three major reservoirs proposed at Meramec Park, Union, and Pine Ford versus numerous smaller reservoirs on tributary streams. For the purpose of this comparison, it was assumed that reservoirs would be built at or very near the mouths of 20 different streams tributary to the Meramec, Big, and Bourbeuse Rivers upstream of Eureka on the Meramec River. The drainage area of the individual tributary streams varied from 36 square miles to 382 square miles, with the total area controlled by this method being 2,100 square miles. This compares with a controlled drainage area of 3,050 square miles above the three major sites mentioned above. An assumed runoff of 1 inch over the entire basin was routed downstream to Eureka, with each of the systems considered to be in place. This study indicated that the three major reservoirs had essentially the same flood control capability at Eureka as the 20 tributary reservoirs.

59. ROUTING THROUGH RESERVOIR STORAGE

Storage requirements for flood control at each proposed reservoir site were established as 100 percent of design storm at individual site less flood control release over a period of time equivalent to the width of the natural hydrograph at a flow equal to that established as "non-damaging". Once the spillway crest elevation was established at each site, routings to determine surcharge were made following procedure outlined in an article by H. K. Barrows, entitled "Reservoir Storage Above Spillway Level", appearing in "Engineer Notebook" of American Society of Civil Engineers' publication "Civil Engineering".

60. FREQUENCY FLOOD PROFILES FOR NATURAL CONDITIONS

In developing flood profiles for various frequency storms, the generalized frequency curves previously discussed were used to compute peak flows at key points where sufficient field data were available to derive rating curves. These peak flows thus developed were applied to the rating curves to establish elevation at these points. These points were then connected to form a flood profile using riverbed profiles and high-bank profiles as guides in shaping the profiles between key points.

61. FREQUENCY FLOOD PROFILES FOR MODIFIED CONDITIONS

Several basic assumptions were made in this phase of the study. It was agreed that points on the profiles for modified conditions should be developed at the same key points as used in natural conditions. A further assumption was made that, since the storm resulting in any given frequency flood at a given point in the basin remains unchanged whether or not flood control projects were in place, the same c.f.s. per square mile factor used in deriving points under natural conditions can be used for modified conditions but that the drainage area must be reduced by the area controlled by the reservoir or system of reservoirs. Since time is not a factor and precisely the same storm does not result in the same frequency flood in different parts of the basin and, furthermore, peak flow alone determines flood profiles, it was felt that this approach was surely as accurate as the basic data available. The alternative approach would be a very complex development of frequency flood hydrographs for innumerable locations within the basin and routing of these flows through many alternate systems of reservoirs. For those reservoirs in which flood control storage was not sufficient to completely control, a series of routings for floods of greater frequency was made to determine at what frequency control became negligible.

62. DRAINAGE AREA VERSUS TIME OF TRAVEL

Upon completion of the routing studies, which established lag constants for the basin, it was possible to combine these results with those developed in paragraph 47 and prepare a map of drainage area versus time of travel. In this study, the time of travel was computed to the key gaging station at Eureka. This map is shown on PLATE C-23.

SECTION VI - HYPOTHETICAL FLOODS AND DESIGN CAPACITIES

63. PROBABLE MAXIMUM PRECIPITATION FOR MERAMEC RIVER BASIN

At the request of the Office, Chief of Engineers, the Hydrometeorological Section of the U. S. Weather Bureau prepared an estimate of probable maximum precipitation for the Meramec River Basin in December 1961. The estimate, so prepared for duration and depth for the total drainage area of 3,955 square miles, is tabulated below.

Probable maximum precipitation for Meramec River Basin

Duration (hr.)	6	12	18	24	30	36	42	48	54	60	66	72
Depth (in.)	9.2	11.9	13.6	15.1	16.2	17.2	18.0	18.8	19.3	19.7	20.1	20.5

The curves for areas up to 1,000 square miles are from Hydrometeorological Report No. 33, while those for larger areas are from the envelope of observed storm depths adjusted for moisture and transposition. Three storms control the areas of 1,000 square miles and greater. The Bonaparte, Iowa, storm of 9-10 June 1905 (UMV 2-5) controls for the shorter durations; the Hallett, Oklahoma, storm of 2-6 September 1940 (SW 2-18) controls the 12- and 24-hour durations of 1,000- and 2,000-square mile areas; the Warner, Oklahoma, storm of 6-12 May 1943 (SW 2-20) controls the larger durations. The area-depth curves were modified somewhat in the larger areas to make a smooth transition to those of the adjusted storm data. The Meramec River Basin is shaped somewhat like a parallelogram with its long axis oriented northeast-southwest and, therefore, climatologically favorable for a good fit for many observed isohyetal patterns with little or no rotation. An idealized elliptical isohyetal pattern was therefore used for the total area of the basin. A basin shape factor of 0.93 was determined as the portion of the pattern storm which would fall within the Meramec Basin assuming the best fit. The 6-hour rainfall increments were arranged in critical time sequence as shown on Plate 10 of Civil Works Engineer Bulletin No. 52-8.

64. STANDARD PROJECT FLOOD - GENERAL

The "standard project flood" is defined, in general, as the runoff hydrograph from the "standard project storm" and is used as a standard against which the degree of flood protection may be compared with similar projects in other localities. The standard project storm estimate represents the most severe flood producing rainfall depth-area-duration relationship and isohyetal pattern of a storm that is

considered to be characteristic of the region in which the basin is located after consideration is given to the runoff characteristics of the basin. In this study, the standard project storm was assumed to be 50 percent of the probable maximum precipitation, with a rainfall isohyetal pattern similar to that shown on Plate 12 of Civil Works Engineer Bulletin No. 52-8.

65. STANDARD PROJECT STORM - GAGING STATIONS

The procedure outlined in Civil Works Engineer Bulletin No. 52-8 was used in arranging the standard project storm 6-hour rainfall increments in the most critical time sequence. The standard project flood hydrograph, generated by the standard project storm, was computed using infiltration rates of 1.00 inch for initial loss and 0.08 inch per hour thereafter. The standard project flood was computed at each of the seven presently active gaging stations on the three principal rivers in the basins with the storm centered (1) over the entire Meramec Basin, (2) over the Big River Basin, (3) over the Bourbeuse River Basin, and (4) over the Meramec River alone. The results are shown in TABLE C-13.

66. STANDARD PROJECT STORM - RESERVOIRS

Standard project storms were also centered above each of the major and intermediate reservoir sites. Flood control storage allocation at the major sites was based on complete containment of standard project flood runoff less flood control releases. At the intermediate reservoir sites, the standard project flood hydrograph was routed through the spillway to determine surcharge and in turn establish top of embankment.

67. RESERVOIR DESIGN FLOODS

At all reservoir sites classed as major, the reservoir design flood was the standard project flood resulting from the standard project storm centered above the reservoir site. However, for reservoirs classed as intermediate and headwater, the design flood was computed as the runoff from a 50-year storm less flood control releases for the duration of the runoff hydrograph. Basically, the rainfall used was the 6-hour, 50-year rainfall at St. Louis, Missouri, expanded into a 24-hour storm, adjusted for drainage area, and arranged in a critical time sequence. A total of 24 storms which occurred over or immediately adjacent to the Meramec River Basin was analyzed for depth-area-duration relationship. The individual storms were broken down into 6-hour increments occurring over 10-, 100-, and 200-square mile areas. These data were then plotted into two curves, one of which presented an average accumulation of rainfall in percentage of the 6-hour, 10-square mile value. The other curve presented a drainage area

adjustment in percentage of the 10-square mile value. By use of these curves, the 6-hour, 50-year rainfall was expanded into a 24-hour storm for each drainage area involved. After arrangement into critical time sequence, initial losses of 0.5 inch and hourly losses of 0.06 inch per hour were applied to determine runoff. Pertinent data on the design floods and reservoir flood control capacities for the project are shown in TABLE C-14. The flood control storage tabulated in TABLE C-14 is that required to contain the design flood runoff as computed. However, in the economic evaluation, it was found that at some reservoir sites this flood control storage could not be justified and a reallocation of storage was made, whereby flood control storage was reduced and joint-use storage increased by an equal amount, thereby resulting in the same height of dam at most sites. The final determination of storage is shown in TABLE C-14A.

68. LEVEE DESIGN FLOODS

In instances where levees were considered for a locality, and hazard to human life and protection of highly valuable property are involved, a high degree of protection was assumed warranted. In planning protection for such areas, a flood of the magnitude of the 200-year frequency was used. In agricultural or sparsely populated rural areas, protection against a flood equal in magnitude to the 50-year frequency was studied. The 200-year and 50-year frequency flood profiles, as modified by reservoir operation by the method outlined in paragraph 61, were superimposed on backwater curves resulting from coincidental floods of the same frequency on the Mississippi River. The condition assumed on the Mississippi River was the "EN" reservoir condition. Modified flows at Eureka for the 200- and 50-year floods are 65,000 c.f.s. and 45,000 c.f.s., respectively. To the resulting profiles, 2 feet of freeboard were added to establish the levee grade.

69. SPILLWAY DESIGN CAPACITIES

"Spillway design flood (SDF)" is defined as the hydrograph selected as a basis for estimating spillway design capacities and spillway surcharges. In this survey, the "spillway design flood" was the runoff hydrograph from the probable maximum precipitation for all sites classed as major and the 100-year flood for all other sites.

70. SPILLWAY DESIGN FLOOD

To determine the reservoir inflow hydrographs for the spillway design flood, the spillway design storm runoff was applied to the inflow unit hydrograph at the various damsites. Runoff from the areas adjacent to the reservoirs, plus 100 percent runoff for the area covered by the full reservoir, was added to the inflow. Pertinent data for all projects included in this plan are shown in TABLE C-14.

71. SPILLWAY LENGTHS

In estimating spillway length requirements, the spillway design flood was routed through reservoir storage assuming various spillway crest lengths. It was assumed that, when the spillway design flood occurred, the reservoir would be with the water surface at spillway crest. Based on these assumptions, the spillway design flood was routed through reservoir storage for various spillway lengths, and by economic analysis recommended spillway length was chosen for major sites. For intermediate reservoir sites, essentially the same procedure was followed. However, surcharge limitations as dictated by paragraph 9c(2) of EM 1110-2-1101, "Engineering and Design, Project Formulation and Design Criteria for Small Dams", resulted in some spillway crest lengths which were incompatible with topography at the reservoir sites. Therefore, an economic study was made of 50-foot concrete spillway crest length versus the much longer earth spillways. As a result, 50-foot concrete spillways are planned at all intermediate sites, with the exception of I-21, I-28, and I-32. These three sites have grass spillways with respective lengths of 365 feet, 625 feet, and 1,100 feet.

72. FREEBOARD REQUIREMENTS

Preliminary estimates of freeboard requirements at each of the reservoirs indicated that in no case would minimum requirements be exceeded. Therefore, minimum freeboard requirements of 5 feet were set at all reservoir sites, whether major or intermediate.

73. OUTLET DESIGN CAPACITIES

For those outlets at multi-purpose projects, where releases for water supply and flood control are combined in a single outlet through the dam, maximum design capacities are generally based on flood control requirements. This is true in this basin as flood control releases are considerably larger than maximum releases required for water supply.

74. OUTLET SIZE CRITERIA

For planning purposes, the outlet capacities are based within the framework of the following criteria:

a. Since the outlet will also serve as the diversion during construction of the dam, the structures were sized to pass downstream non-damaging flow with water surface at bottom of flood control pool. This also encompasses the need for bankfull release as soon as inflow reaches that magnitude of flow.

b. The capacity of outlet works will also be capable of evacuation of all flood control storage in a reasonably short duration after flood period.

c. Additional gates have been provided in the outlet structure for discharge of suitable water for water quality control.

75. INACTIVE STORAGE CAPACITIES

Reservoir storage allocated as inactive storage consists mainly of the volume reserved for sediment accumulation over the assumed life of the project. It should be noted that a portion of the sediment will be deposited outside the limits of the inactive pool but within the over-all limits of the reservoir. The U. S. Geological Survey collected silt samples at a number of locations within the Meramec River Basin. Analysis of these samples resulted in the development of a curve of drainage area versus sediment production in tons per square mile annually, which is applicable to the basin as a whole. This curve was then used in determination of silting potential at all damsites. TABLE C-15 indicates 100-year silt accumulation based on the assumption that all projects are in place and operating and that each reservoir has a 90 percent retention factor.

Climatological data

Meramec River Basin
Long-term mean temperatures

Station	Period of record	Jan	Feb	Mar	Apr	May	Jun	J
Arcadia	37	33.7	36.4	44.3	55.4	63.7	73.1	77
Farmington IE	50	35.1	37.9	45.7	56.3	64.9	74.6	78
Rolla MSM	61	33.7	36.6	44.7	56.1	65.9	74.1	78
St. Louis Airport	24	32.2	35.7	44.4	55.6	65.4	75.1	79
St. Louis City	124	33.3	36.7	45.3	56.5	66.2	75.8	80
St. Louis University	49	34.1	36.8	45.0	56.6	66.6	76.7	81
Salem	57	34.1	37.0	44.9	55.5	64.2	73.9	78
Average	57	33.7	36.7	44.9	56.0	65.3	74.8	79

2

. data

Basin
peratures

ay	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
.7	73.1	77.1	76.0	68.5	57.8	44.6	35.7	55.5
.9	74.6	78.5	76.8	69.5	58.8	45.4	36.9	56.7
.9	74.1	78.6	77.0	69.7	59.6	45.1	35.8	56.3
.4	75.1	79.7	77.7	70.4	59.4	45.0	35.1	56.3
.2	75.8	80.6	78.6	71.4	60.6	46.0	36.2	57.3
.6	76.7	81.1	78.9	71.5	60.8	45.9	36.3	57.5
.2	73.9	78.0	76.4	68.7	58.5	44.8	36.0	56.0
.3	74.8	79.1	77.3	70.0	59.4	45.3	36.0	56.6

TABLE C-1

Precipitation network - monthly and annu
Meramec River Basin

Station	Years of record	Jan	Feb	Mar	Apr	May	Jun
* St. Louis City	124	2.32	1.88	3.64	4.01	4.10	3.80
* Hermann	87	2.03	1.75	2.88	3.79	4.56	4.81
* St. Charles	83	2.27	2.05	3.17	3.81	3.82	3.67
* Arcadia	83	3.08	2.49	3.92	4.25	4.73	4.54
* Jeff. City (Lincoln U.)	79	2.02	1.94	2.46	3.72	4.90	4.65
* Rolla MSM	77	2.21	2.21	3.17	3.81	4.94	5.64
Pacific	72						
* Farmington 1E	64	2.89	2.54	3.70	4.16	4.78	4.11
* Salem	60	2.27	2.53	3.70	4.20	5.14	4.77
Jerome	59						
* St. Louis University	49	2.23	2.25	3.40	3.59	3.54	3.54
* Union 1SE	44	2.12	1.95	3.02	3.75	4.45	4.30
Valley Park	44						
* Fredericktown	36	3.42	2.65	3.75	4.10	4.43	4.19
* St. Louis Airport	30	1.92	1.66	3.42	3.93	4.02	4.37
* Long-term Averages	68	2.40	2.16	3.35	3.93	4.45	4.37

2

- monthly and annual mean
: River Basin

Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
.01	4.10	3.80	2.91	3.77	3.38	2.90	2.72	2.43	37.86
.79	4.56	4.81	2.82	3.53	3.76	3.23	2.88	1.81	37.85
.81	3.82	3.67	2.94	3.45	3.25	2.96	2.79	1.95	36.13
.25	4.73	4.54	3.32	3.04	3.36	3.60	3.74	2.44	42.51
.72	4.90	4.65	2.92	4.27	4.22	3.55	2.84	1.96	39.45
.81	4.94	5.64	3.12	3.94	3.76	3.69	2.85	2.12	41.46
.16	4.78	4.11	3.75	3.20	3.66	3.42	3.38	2.22	41.81
.20	5.14	4.77	2.79	3.38	3.82	3.61	3.11	2.51	41.83
.59	3.54	3.54	3.11	3.72	2.89	2.70	2.45	2.02	35.44
.75	4.45	4.30	3.37	3.31	3.56	3.12	2.63	1.94	37.52
.10	4.43	4.19	3.45	3.12	3.70	3.51	3.21	2.40	41.93
.93	4.02	4.37	2.58	3.55	3.54	3.08	2.57	2.09	36.73
.93	4.45	4.37	3.09	3.52	3.58	3.28	2.93	2.16	39.22

TABLE C-2

Maximum precipitation in inches
for St. Louis, Missouri

Month	(1) 5 Min.	(1) 10 Min.	(1) 15 Min.	(1) 30 Min.	(1) 1 Hrs.	(1) 2 Hrs.	(2) 1 Days	(2) 2 Days	(2) 3 Days
Jan	0.36	0.44	0.53	0.62	0.75	1.03	3.88	4.39	4.39
Feb	0.29	0.45	0.49	0.63	1.18	1.71	4.44	6.71	6.72
Mar	0.44	0.71	0.87	1.09	1.24	1.59	3.88	4.47	5.04
Apr	0.41	0.63	0.80	1.11	1.40	2.41	6.29	6.29	6.29
May	0.52	0.80	0.93	1.03	1.65	2.32	4.05	7.32	7.60
Jun	0.50	0.77	1.01	1.47	2.40	3.80	8.74	8.74	9.65
Jul	0.60	1.00	1.30	2.23	3.47	3.68	6.94	7.17	7.18
Aug	0.59	1.04	1.39	2.56	3.36	3.46	8.78	13.57	14.54
Sep	0.56	0.87	1.03	1.53	2.42	3.02	4.19	4.49	4.75
Oct	0.42	0.57	0.73	0.90	1.19	1.52	3.98	5.20	5.57
Nov	0.26	0.37	0.48	0.56	0.78	0.96	3.61	3.76	3.84
Dec	0.40	0.53	0.59	0.64	0.71	0.97	3.04	3.23	3.26

(1) 1903 to 1961, inclusive

(2) 1871 to 1961, inclusive

TABLE C-3

Monthly runoff of Meramec River at Eureka
Cubic feet per second

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1922	1790	2280	7320	15400	2860	1020	985	729	640	791	686	1630
1923	2240	3850	7330	3370	4980	4880	999	1510	798	675	939	380
1924	1370	2610	3120	4650	6240	7940	3250	2120	1430	684	644	3550
1925	1380	2490	2270	2750	1960	1800	1450	648	1850	2820	5070	3730
1926	1820	4310	4030	5880	1450	803	497	820	1390	3760	4660	2240
1927	5540	3840	6250	22600	11400	8350	1260	1200	773	2620	5790	7250
1928	3340	3060	3060	9060	3240	14800	2880	1710	798	704	786	1100
1929	1990	1390	4550	7390	15100	3580	1420	949	653	1740	1930	3280
1930	8920	6380	4520	1700	970	673	614	396	870	573	587	805
1931	572	1120	1900	2350	2720	1470	689	473	765	571	1140	1700
1932	4200	2470	1570	1100	708	590	629	1640	475	438	829	1340
1933	2750	1100	2580	6777	13600	1260	604	733	662	1120	641	650
1934	953	569	3007	2790	1747	922	356	1073	5478	2407	1932	3666
1935	4024	2023	9855	3901	8976	16000	5659	1474	784	1014	4507	1506
1936	976	1949	1516	2953	822	503	318	255	485	1149	2312	711
1937	7651	4149	2253	3934	8010	4800	1549	654	471	569	510	1917
1938	1637	8428	6624	7178	9081	7539	1466	758	586	427	1943	1469
1939	2323	6232	6739	12390	2799	1776	2677	2062	584	592	821	670
1940	1038	1256	2815	3883	2799	1952	1078	1056	496	436	882	1601
1941	2284	1143	671	7513	1562	820	506	510	1377	3850	5209	2145
1942	1622	6529	3354	4138	4762	13890	2744	949	616	689	3390	9296
1943	3945	1523	3071	2388	15860	7188	1142	1204	684	653	865	690
1944	753	1117	4757	8044	8289	1420	601	526	504	573	511	581
1945	562	2309	13390	20000	4431	18070	2255	771	3597	3600	1278	1125
1946	3867	7090	4182	2102	6263	1836	620	1855	756	575	7317	3012
1947	2414	1750	2194	12770	4759	3394	4455	772	592	847	1973	826
1948	4490	2532	7233	3568	3140	2874	5631	1061	560	622	1212	870
1949	9918	8251	6706	3381	2077	3433	2901	890	2682	12120	1569	3954
1950	17320	6588	6910	6387	10770	4241	1125	4286	4396	1062	1638	1164
1951	2748	10350	7229	4363	3249	3230	12600	4175	3268	3019	7086	3782
1952	2903	4810	6467	8551	1752	943	823	1077	632	589	927	991
1953	1240	1107	4544	3663	2510	849	553	407	297	418	486	511
1954	530	538	514	945	924	2830	474	386	486	705	630	1167
1955	1178	2652	5591	1798	1242	1405	1471	544	408	548	629	426
1956	374	1453	949	969	4141	2633	844	428	244	236	464	1250
1957	768	4210	7082	15500	17730	11490	11500	1405	615	578	1224	3340
1958	1939	1847	9949	4330	3072	3110	4983	2780	921	717	1822	1255
1959	1925	3186	4054	2126	4595	1522	713	612	545	1231	1382	4436
1960	2553	2065	4715	3737	4187	914	692	554	477	504	913	1811
1961	665	1948	6960	4705	15430	3199	2254	1051	912			
Mean	2963	3313	4796	6026	5505	4246	2207	1163	1114	1442	1978	2226
Max	17320	10350	13390	22600	17730	18070	12600	4286	5478	12120	7317	9296
Min	374	538	514	945	708	503	318	255	244	236	464	426

Average Monthly Runoff for Period of Record 3,096
Maximum Mean Monthly 22,600 April 1927
Minimum Mean Monthly 236 October 1956

TABLE C-4

Hydraulic data
Runoff extremes and means
Meramec River Basin

	Year	Stage		Discharge
Steelville (1922-1961)				
Maximum (period of record)	6/26/35	23.39		47,800
	6/9/45	24.30		47,000
Maximum (known)	8/20/15	26.5		60,000
Minimum (period of record)	7/22/34	0.35		74
Mean	-	-	(39 yrs)	585
Sullivan (1921-1933)-(1943-1961)				
Maximum (period of record)	6/9/45	32.0		77,300
Maximum (known)	8/21/15	33.5		90,000
Minimum (period of record)	9/20-22/56	1.27		131
Mean	-	-	(30 yrs)	1,209
Spring Bluff (1943-1961)				
Maximum (period of record)	6/30/57	34.71		50,700
Maximum (known)	8/-/15	35.7		-
Minimum (period of record)	Discharges below 1,000 c.f.s. are not computed			
Mean				
Union (1921-1961)				
Maximum (period of record)	7/1/57	24.44		33,100
Maximum (known)	8/22/15	28.5	(est.)	50,000
Minimum (period of record)	10/10/56	0.59		11
Mean	-	-	(40 yrs)	652
DeSoto (1948-1961)				
Maximum (period of record)	6/30/57	27.15		55,800
Maximum (known)	8/-/15	29.4		70,500
Minimum (period of record)	9/19/54	2.02		20
Mean	-	-	(13 yrs)	707
Byrnesville (1921-1961)				
Maximum (period of record)	7/1/57	26.41		42,100
Maximum (known)	8/21/15	30.2		80,000
Minimum (period of record)	8/14/34	1.50		42
	8/30/36	1.54		25
Mean	-	-	(40 yrs)	857
Eureka (1903-1906)-(1921-1961)				
Maximum (period of record)	6/11/45	36.94		120,000
Maximum (known)	8/22/15	40.2		175,000
Minimum (period of record)	8/27/36			
	8/31/36			
	9/1/36	0.34		196
Mean	-	-	(42 yrs)	3,096

TABLE C-5

Meramec River at Eureka, Missouri
Subnormal runoff

Month	Period of record mean second feet	Actual monthly mean second feet	Percent of normal	Actual monthly mean second feet	Percent of normal	Actual monthly mean second feet	Percent of normal	Actual monthly mean second feet	Percen of norma
		(1930)		(1933)		(1939)		(1952)	
January	2963								
February	3313								
March	4796	4520	94.2%						
April	6026	1700	28.2%						
May	5505	970	17.6%					1752	31.8
June	4246	673	15.8%	1260	29.7%			943	22.2
July	2207	614	27.8%	604	27.4%			823	37.3
August	1163	396	34.0%	733	15.9%			1077	92.6
September	1114	870	78.1%	662	59.4%	584	52.4%	632	56.7
October	1442	573	39.7%	1120	77.7%	592	41.0%	589	40.8
November	1978	587	29.7%	641	32.4%	821	24.1%	927	46.9
December	2226	805	36.1%	650	29.2%	670	30.1%	991	44.5
		(1931)		(1934)		(1940)		(1953)	
January	2963	572	19.3%	953	32.1%	1038	35.0%	1240	41.8
February	3313	1120	33.8%	569	17.2%	1256	37.9%	1107	33.4
March	4796	1900	39.6%	3007	62.7%	2815	15.9%	4544	94.7
April	6026	2350	39.0%	2790	46.3%	3883	21.6%	3663	60.8
May	5505	2720	49.4%	1747	31.7%	2799	31.5%	2510	45.6
June	4246	1470	34.6%	922	21.7%	1952	21.7%	849	20.0
July	2207	689	31.2%	356	16.1%	1078	48.9%	553	25.1
August	1163	473	40.7%	1073	92.3%	1056	90.8%	407	35.0
September	1114	765	68.7%			496	44.5%	297	26.7
October	1442	571	39.6%			436	30.2%	418	29.0
November	1978	1140	57.6%			882	44.6%	486	24.6
December	2226	1700	76.3%			1601	71.9%	511	23.0
						(1941)		(1954)	
January	2963					2284	77.1%	530	17.9
February	3313					1143	34.5%	538	16.2
March	4796					671	14.0%	514	10.7
April	6026							945	15.7
May	5505							924	16.8
June	4246							2830	66.7
July	2207							474	21.5
August	1163							386	33.2
September	1114							486	43.6
October	1442							705	48.9
November	1978							630	31.9
December	2226							1167	52.4
								(1955)	
January	2963							1178	39.8
February	3313							2652	80.0
March	4796								
		1235		1139		1371		1126	
Total Period		3076	40.1%	2973	38.3%	2885	47.5%	2945	38.2

2

at Eureka, Missouri
rmal runoff

nt al	Actual monthly mean second feet	Percent of normal	Actual monthly mean second feet	Percent of normal	Actual monthly mean second feet	Percent of normal	Actual monthly mean second feet	Percent of normal
	(1952)		(1955)		(1958)		(1960)	
							2553	86.2%
							2065	62.3%
							4715	98.3%
			1798	29.8%			3737	62.0%
	1752	31.8%	1242	22.5%			4187	76.1%
	943	22.2%	1405	33.0%			914	21.5%
	823	37.3%	1471	66.7%			692	31.4%
	1077	92.6%	544	46.8%			554	47.6%
.4%	632	56.7%	408	36.6%	921	82.7%	477	42.8%
.0%	589	40.8%	548	38.0%	717	49.7%	504	35.0%
.1%	927	46.9%	629	31.8%	1822	92.1%	913	46.2%
.1%	991	44.5%	426	19.1%	1255	56.4%	1811	81.3%
	(1953)		(1956)		(1959)		(1961)	
.0%	1240	41.8%	374	12.6%	1925	65.0%	665	22.4%
.9%	1107	33.4%	1453	43.8%	3186	96.2%	1948	58.8%
.9%	4544	94.7%	949	19.8%	4054	84.5%		
.6%	3663	60.8%	969	16.1%	2126	35.3%		
.5%	2510	45.6%	4141	75.2%	4595	83.5%		
.7%	849	20.0%	2633	62.0%	1522	35.8%		
.9%	553	25.1%	844	38.2%	713	32.3%		
.8%	407	35.0%	428	36.8%	612	52.6%		
.5%	297	26.7%	244	21.9%	545	48.9%		
.2%	418	29.0%	236	16.4%	1231	85.3%		
.6%	486	24.6%	464	23.5%	1382	69.9%		
.9%	511	23.0%	1250	56.1%				
	(1954)		(1957)					
.1%	530	17.9%	768	25.9%				
.5%	538	16.2%						
.0%	514	10.7%						
	945	15.7%						
	924	16.8%						
	2830	66.7%						
	474	21.5%						
	386	33.2%						
	486	43.6%						
	705	48.9%						
	630	31.9%						
	1167	52.4%						
	(1955)							
	1178	39.8%						
	2652	80.0%						
.5%	1126 / 2945	38.2%	1056 / 2993	35.3%	1774 / 2768	64.1%	1838 / 3090	59.5%

TABLE C-6

Big River at Byrnesville, Missouri
Subnormal runoff

Month	Period of record mean second feet	Actual monthly mean flow second feet	Percent of normal	Actual monthly mean flow second feet	Percent of normal	Actual monthly mean flow second feet	Percent of normal	Actua month mean flow secon feet
		(1930)		(1933)		(1939)		(1953
January	935							
February	1022							
March	1387	1030	74.3%					
April	1644	408	24.8%					1083
May	1514	228	15.1%					867
June	992	155	15.6%	229	23.1%			272
July	632	170	26.9%	180	28.4%			142
August	308	73	23.7%	181	58.8%			90
September	287	212	73.9%	269	93.7%	137	47.7%	70
October	360	154	42.8%	303	84.2%	204	56.7%	99
November	571	129	22.6%	165	28.9%	282	49.4%	118
December	646	160	24.8%	192	29.7%	183	28.3%	118
		(1931)		(1934)		(1940)		(1954
January	935	116	12.4%	281	30.1%	351	37.5%	134
February	1022	212	20.7%	147	14.4%	453	44.3%	139
March	1387	397	28.6%	862	62.1%	645	46.5%	137
April	1644	801	48.7%	855	52.0%	1037	63.1%	394
May	1514	487	32.2%	649	42.9%	836	55.2%	204
June	992	220	22.2%	160	16.1%	532	53.6%	979
July	632	133	21.0%	90	14.2%	240	38.0%	141
August	308	123	39.9%	183	59.4%	296	96.1%	84
September	287	259	90.2%			105	36.6%	198
October	360	215	59.7%			114	31.7%	180
November	571	399	69.9%			364	63.7%	142
December	646	517	80.0%			640	99.1%	450
						(1941)		(1955
January	935					747	79.9%	312
February	1022					311	30.4%	703
March	1387					195	14.1%	
April	1644					1352	82.2%	
May	1514					253	16.7%	
June	992					142	14.3%	
July	632					115	18.2%	
August	308					122	39.6%	
September	287							
October	360							
November	571							
December	646							
January	935							
February	1022							
March	1387							
Total Period		300 / 847	35.4%	316 / 815	38.9%	402 / 858	46.9%	30 / 83

nesville, Missouri
al runoff

2

l ly d	Percent of normal	Actual monthly mean flow second feet	Percent of normal	Actual monthly mean flow second feet	Percent of normal	Actual monthly mean flow second feet	Percent of normal
)		(1953)		(1955)		(1960)	
						791	84.6%
						708	69.3%
						1303	93.9%
		1083	65.9%	563	34.2%	1017	61.9%
		867	57.3%	424	28.0%	1206	79.7%
		272	27.4%	342	34.5%	289	29.1%
		142	22.5%	453	71.7%	189	29.9%
		90	29.2%	98	31.8%	139	45.1%
7	47.7%	70	24.4%	68	23.7%	152	53.0%
4	56.7%	99	27.5%	93	25.8%	146	40.6%
2	49.4%	118	20.7%	176	30.8%	403	70.6%
5	28.3%	118	18.3%	103	15.9%	586	90.7%
0)		(1954)		(1956)		(1961)	
1	37.5%	134	14.3%	94	10.1%	189	20.2%
3	44.3%	139	13.6%	608	59.4%	738	72.2%
5	46.5%	137	9.9%	271	19.5%		
7	63.1%	394	24.0%	362	22.0%		
6	55.2%	204	13.5%	1303	86.1%		
2	53.6%	979	98.7%	492	49.6%		
0	38.0%	141	44.8%	146	23.1%		
6	96.1%	84	27.3%	98	31.8%		
5	36.6%	198	69.0%	49	17.1%		
4	31.7%	180	50.0%	50	13.9%		
4	63.7%	142	24.9%	117	20.5%		
0	99.1%	450	69.6%	243	37.6%		
1)		(1955)		(1957)			
7	79.9%	312	33.4%	238	25.5%		
1	30.4%	703	68.8%				
5	14.1%						
2	82.2%						
3	16.7%						
2	14.3%						
5	18.2%						
2	39.6%						
2	46.9%	307	36.8%	290	35.1%	561	64.1%
8		835		827		875	

TABLE C-7

Bourbeuse River at Union, Missouri
Subnormal runoff

Month	Period of record mean second feet	Actual monthly mean flow second feet	Percent of normal	Actual monthly mean flow second feet	Percent of normal	Actual monthly mean flow second feet	Percen of normal
		(1930)		(1933)		(1939)	
January	590						
February	682						
March	1094	774	70.7%				
April	1234	201	16.3%				
May	1205	100	8.3%				
June	1022	59	5.8%	151	14.8%		
July	365	73	20.0%	55	15.1%		
August	190	27	14.2%	45	23.7%	173	91.0%
September	213	209	98.1%	131	61.5%	39	18.3%
October	340	47	13.8%	229	67.4%	28	8.2%
November	416	47	11.3%	65	15.6%	45	10.8%
December	460	130	28.3%	59	12.8%	38	8.3%
		(1931)		(1934)		(1940)	
January	590	51	8.6%	141	23.9%	54	9.2%
February	682	259	38.0%	49	7.2%	310	45.4%
March	1094	575	52.6%	1043	95.3%	561	51.3%
April	1234	255	20.7%	529	42.9%	659	53.4%
May	1205	1190	98.8%	121	10.0%	309	25.6%
June	1022	476	46.6%	305	29.8%	222	21.7%
July	365	86	23.6%	37	10.1%	109	29.9%
August	190	52	27.4%			75	39.5%
September	213	149	70.0%			51	23.9%
October	340	47	13.8%			26	7.6%
November	416	184	44.2%			29	7.0%
December	460	455	98.9%			75	16.3%
						(1941)	
January	590					427	72.4%
February	682					154	22.6%
March	1094					62	5.7%
April	1234						
May	1205						
June	1022						
July	365						
August	190						
September	213						
October	340						
November	416						
December	460						
January	590						
February	682						
March	1094						
Total Period		252 / 652	38.7%	211 / 657	32.1%	172 / 590	29.2%

2

Union, Missouri
runoff

Actual monthly mean flow second feet	Percent of normal	Actual monthly mean flow second feet	Percent of normal	Actual monthly mean flow second feet	Percent of normal
(1939)		(1952)		(1955)	
				1078	98.5%
				282	22.8%
				173	14.4%
				390	38.2%
				289	79.2%
173	91.0%			77	40.5%
39	18.3%	55	25.8%	78	36.6%
28	8.2%	40	11.8%	65	19.1%
45	10.8%	60	14.4%	45	10.8%
38	8.3%	75	16.3%	37	8.0%
(1940)		(1953)		(1956)	
54	9.2%	231	39.2%	31	5.3%
310	45.4%	172	25.2%	160	23.5%
561	51.3%	868	79.3%	99	9.0%
659	53.4%	987	80.0%	95	77.0%
309	25.6%	343	28.5%	754	62.6%
222	21.7%	64	6.3%	741	72.5%
109	29.9%	47	12.9%	172	47.1%
75	39.5%	49	25.8%	50	26.3%
51	23.9%	25	11.7%	19	8.9%
26	7.6%	30	8.9%	15	44.1%
29	7.0%	28	6.7%	46	11.1%
75	16.3%	35	7.6%		
(1941)		(1954)			
427	72.4%	38	6.4%		
154	22.6%	42	6.2%		
62	5.7%	42	3.8%		
		164	13.3%		
		257	21.3%		
		522	51.1%		
		50	13.7%		
		40	21.0%		
		33	15.5%		
		92	27.1%		
		63	15.1%		
		128	27.8%		
		(1955)			
		150	25.4%		
172/590	29.2%	163/608	26.8%	224/661	33.9%

TABLE C-8

Infiltration capacities
Meramec River and tributaries

Infiltration capacity in inches per hour	Number of occurrences
Less than .01	5
.01 to .02	9
.02 to .03	16
.03 to .04	19
.04 to .05	28
.05 to .06	33
.06 to .07	22
.07 to .08	17
.08 to .09	10
.09 to .10	12
.10 to .15	23
.15 to .20	6
More than .20	2
Total	202

TABLE C-9

		Meramec River at Eureka	Meramec River at Sullivan	Meramec River at Steelville	Bourbeuse River at Union	Bourbeuse River at Spring Bluff	Big River at Byrnesville
D.A.	(Sq.Mi.)	3,788	1,475	781	808	608	917
L	(Miles)	186.9	105.6	72.4	131.6	59.7	123.3
Lca	(Miles)	91.7	72.0	48.3	91.9	35.0	59.6
Q_p	(cfs)	33,653	21,350	17,800	10,145	12,250	12,750
q_p	(cfs/sq.mi.)	8.88	14.47	22.79	12.56	20.15	13.90
t_p	(Hours)	66.0	35.0	29.5	65.0	33.0	48.0
W_{50}	(Hours)	68.0	35.0	23.1	48.4	31.0	40.8
W_{75}	(Hours)	43.0	20.5	14.2	26.6	16.0	24.4
C_t		3.54	2.40	2.54	3.87	3.18	3.33
C_p640		586	506	672	816	665	667
t_r	(Hours)	6	6	6	6	6	6

Discharge (c.f.s.)

(Hours)	Meramec River at Eureka	Meramec River at Sullivan	Meramec River at Steelville	Bourbeuse River at Union	Bourbeuse River at Spring Bluff	Big River at Byrnesville
0	0	0	0	0	0	0
6	170	750	680	250	340	200
12	1,660	3,840	2,100	800	3,000	700
18	7,850	7,450	5,800	1,600	5,800	2,400
24	11,350	12,750	12,400	2,600	7,800	4,700
30	13,250	17,250	16,650	3,800	10,000	7,400
36	16,000	20,600	15,800	5,000	12,250	9,600
42	19,800	20,000	10,600	6,100	10,400	11,200
48	24,400	16,400	6,400	7,100	6,900	12,600
54	28,300	12,300	3,900	8,200	3,600	12,100
60	31,050	9,200	2,500	9,200	2,000	9,800
66	33,250	7,200	1,750	10,000	1,000	7,200
72	33,050	5,700	1,350	9,300	650	5,000
78	31,250	4,400	1,080	7,300	450	3,500
84	28,750	3,400	840	5,300	350	2,600
90	26,000	2,600	650	3,500	250	1,950
96	22,750	2,200	500	2,200	200	1,450
102	19,150	1,850	380	1,400	150	1,150
108	14,900	1,600	280	900	100	940
114	10,750	1,400	190	630	70	780
120	7,750	1,250	110	500	50	650
126	6,000	1,100	40	390	30	560
132	4,700	1,000	0	290	10	480
138	3,750	900		190	0	410
144	2,900	800		130		350
150	2,350	700		100		290
156	1,850	600		70		230
162	1,450	500		40		170
168	1,100	400		20		110
174	750	300		0		50
180	550	175				30
186	300	25				20
192	200	0				10
198	107					0
204	0					
Total	407,437	158,640	84,000	86,910	65,400	98,630

ERAMEC RIVER BASIN

Big River at Byrnesville	Big River at DeSoto	Dry Fork River near St. James	Courtois Creek near Berryman	Huzzah Creek near Dillard
917	718	370	173	92
123.3	78.3	67.5	21.5	13.8
59.6	49.5	35.3	10.3	6.1
12,750	16,770	12,350	13,795	11,675
13.90	23.36	33.38	79.74	126.9
48.0	13.0	15.0	5.1	6.3
40.8	22.3	13.4	6.0	4.7
24.4	12.8	8.4	3.6	2.7
3.33	1.09	1.49	1.60	1.67
667	304	501	407	797
6	6	6	3	2

(c.f.s.)			(Hours)		(Hours)	
0	0	0	0	0	0	0
200	2,200	980	3	3,000	2	1,370
700	12,000	4,220	6	13,700	4	4,890
2,400	16,500	12,350	9	10,000	6	9,720
4,700	13,000	8,030	12	4,000	8	9,980
7,400	9,600	4,730	15	2,000	10	1,990
9,600	6,800	3,110	18	1,100	12	530
11,200	5,100	2,180	21	700	14	390
12,600	3,600	1,570	24	550	16	330
12,100	2,200	1,080	27	480	18	230
9,800	1,600	720	30	420	20	170
7,200	1,200	440	33	360	22	90
5,000	850	270	36	300	24	0
3,500	680	120	39	240		
2,600	530	0	42	180		
1,950	430		45	120		
1,450	330		48	60		
1,150	230		51	0		
940	170					
780	120					
650	70					
560	20					
480	0					
410						
350						
290						
230						
170						
110						
50						
30						
20						
10						
0						
98,630	77,230	39,800		37,210		29,690

TABLE C-10

UNIT HYDROGRAPHS AT DAM SITES - MERAM

Site No.		Meramec Park 17	Salem 27	Virginia Mines 40	Union 29	Washington Park 5	Irondale 9	Pine Ford 2a	I-14	I-15A	I-23
D.A.	(Sq.Mi.)	1,508	175	240	754	160	175	788	112	122	35.6
L	(Miles)	107.96	30.60	31.23	122.00	27.03	19.18	93.5	19.60	18.10	10.67
L_{ca}	(Miles)	73.61	18.00	11.75	85.00	13.00	8.33	58.70	10.32	8.16	3.9
Q_p	(c.f.s.)	21,410	10,150	15,160	9,500	10,838	14,733	14,420	9,293	10,939	5,150
q_p	(cfs/sq.mi.)	14.20	58.00	63.17	12.60	67.74	84.19	18.30	82.97	89.66	144.67
t_p	(Hours)	35.78	8.00	8.20	60.00	7.75	6.20	22.40	6.40	5.90	3.85
C_t		2.41	1.36	1.40	3.75	1.35	1.36	1.65	1.31	1.32	1.24
$C_p 640$		508	522	518	756	525	522	410	531	529	557
t_r	(Hours)	6	6	6	6	6	6	6	6	6	6

Discharge (C.F.S.)

(Hours)	Meramec Park 17	Salem 27	Virginia Mines 40	Union 29	Washington Park 5	Irondale 9	Pine Ford 2a	I-14	I-15A	I-23
0	0	0	0	0	0	0	0	0	0	0
6	767	3,355	5,845	233	4,200	9,529	1,500	5,510	8,260	3,291
12	3,926	9,600	13,765	747	8,970	6,621	5,700	3,300	1,740	475
18	7,617	4,100	3,775	1,493	2,647	1,856	10,600	1,280	1,260	63
24	13,035	1,165	1,195	2,426	990	732	14,100	720	740	0
30	17,636	400	660	3,546	343	75	13,300	480	460	
36	21,061	140	370	4,666	60	0	10,000	320	340	
42	20,448	55	165	5,692	0		7,440	240	180	
48	16,768	10	40	6,625			5,600	140	140	
54	12,575	0	0	7,652			4,130	60	0	
60	9,406			8,585			3,000	0		
66	7,361			9,332			2,130			
72	5,828			8,678			1,600			
78	4,498			6,812			1,210			
84	3,476			4,946			970			
90	2,658			3,266			810			
96	2,250			2,053			680			
102	1,891			1,306			580			
108	1,836			840			480			
114	1,431			588			380			
120	1,278			467			280			
126	1,125			364			180			
132	1,022			271			90			
138	920			177			0			
144	818			121						
150	716			93						
156	613			65						
162	511			37						
168	410			19						
174	307			0						
180	180									
186	26									
192	0									
Total	162,194	18,825	25,815	81,100	17,210	18,823	84,760	12,050	13,120	3,829

ES AT DAM SITES - MERAMEC RIVER BASIN STUDY

	I-15A	I-23	I-26	I-28	I-21	I-30	I-32	I-33A	I-35A	I-38	I-41
	122	35.6	27	44	23.5	19.8	60	52	69	121	28.8
0	18.10	10.67	9.83	16.22	7.76	7.77	17.86	17.25	23.90	19.00	9.05
2	8.16	3.98	4.63	6.94	2.76	4.29	8.49	9.11	14.80	11.01	4.68
	10,939	5,150	3,898	4,671	3,219	3,208	4,218	3,653	3,780	7,070	4,270
7	89.66	144.67	144.36	106.15	136.98	162.04	70.30	70.25	54.75	58.41	148.16
0	5.90	3.85	3.90	5.20	5.30	3.53	10.10	10.15	12.95	11.95	3.80
1	1.32	1.24	1.23	1.25	2.10	1.23	2.25	2.22	2.26	2.40	1.23
	529	557	563	552	726	572	710	713	709	698	563
	6	6	6	6	6	6	6	6	6	6	6
	Discharge (C.F.S.)										
	0	0	0	0	0	0	0	0	0	0	0
	8,260	3,291	2,530	3,395	1,835	1,918	677	650	250	330	2,720
	1,740	475	346	1,030	533	207	3,933	3,350	2,650	4,500	380
	1,260	63	28	273	140	5	1,080	915	2,850	5,000	0
	740	0	0	35	20	0	393	230	610	1,400	
	460			0	0		200	170	280	700	
	340						100	130	230	400	
	180						50	90	190	300	
	140						20	50	150	200	
	0						0	10	110	100	
								0	70	60	
									30	20	
									0	0	
	13,120	3,829	2,904	4,733	2,528	2,130	6,453	5,595	7,420	13,010	3,100

TABLE C-11

SUMMATION OF MAJOR TRIBUTARIES IN THE MERA
ROUTED TO EUREKA

	Meramec River										Big River		
Time	Calvey Creek	Lower Meramec River	Indian Creek	Brazil Creek	Huzzah Creek	Courtois Creek	Whittenberg Creek	Dry Fork River	Crooked Creek	Dam Site #27	Mineral Fork	Terre Bleue Creek	Flat River
0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0
18	1,244	0	0	0	0	0	0	0	0	0	49	0	0
24	1,445	1,066	1,040	0	0	0	0	0	0	0	355	48	0
30	1,470	1,265	2,707	218	51	75	0	4	0	10	1,110	214	50
36	226	1,291	3,098	540	367	445	86	45	18	69	2,157	528	206
42	25	225	3,266	674	945	976	200	188	75	216	3,088	898	479
48	0	26	3,357	717	1,619	1,561	322	492	174	469	3,582	1,183	770
54		0	2,337	734	2,339	2,179	447	989	317	822	3,507	1,280	964
60			670	738	3,039	2,741	573	1,668	486	1,237	2,855	1,155	993
66			279	738	3,497	3,021	613	2,467	662	1,665	1,857	849	847
72			111	520	3,656	3,075	625	3,298	822	2,041	948	480	575
78			20	198	3,467	2,784	544	4,029	927	2,282	413	194	284
84			0	64	2,973	2,303	430	4,518	951	2,329	183	50	91
90				21	2,357	1,747	308	4,668	888	2,172	81	8	12
96				4	1,671	1,146	183	4,452	755	1,853	32	1	1
102				0	991	591	57	3,937	589	1,448	10	0	0
108					542	313	17	3,235	414	1,024	2		
114					334	184	5	2,460	253	639	0		
120					208	105	1	1,730	131	340			
126					123	55	0	1,125	50	144			
132					66	26		691	14	49			
138					31	10		420	4	16			
144					12	2		262	1	5			
150					3	0		168	0	1			
156					0			107		0			
162								66					
168								38					
174								20					
180								9					
186								4					
192								1					
198								0					
204													
210													

2

RAMEC RIVER BASIN STUDY

R TRIBUTARIES IN THE MERAMEC RIVER BASIN
ROUTED TO EUREKA

Big River				Bourbeuse River										
Mineral Fork	Terre Bleue Creek	Flat River	Irondale Dam	Spring Creek	Boone Creek	Red Oak Creek	Lower Bourbeuse River	Dry Fork Creek	Brush Creek	Lanes Fork	Total	Local	Natural Eureka	Time
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	170	170	6
0	0	0	0	0	0	0	0	0	0	0	0	1,660	1,660	12
49	0	0	0	0	0	0	0	0	0	0	1,293	6,557	7,850	18
355	48	0	53	0	15	5	0	0	0	0	4,027	7,323	11,350	24
1,110	214	50	249	0	108	52	5	0	0	0	7,588	5,662	13,250	30
2,157	528	206	634	0	281	155	70	3	3	0	10,222	5,778	16,000	36
3,088	898	479	1,171	0	458	282	224	30	50	0	13,470	6,330	19,800	42
3,582	1,183	770	1,774	0	562	419	419	171	200	4	17,821	6,579	24,400	48
3,507	1,280	964	2,343	20	590	557	571	460	430	43	20,929	7,371	28,300	54
2,855	1,155	993	2,721	213	602	657	642	806	642	126	22,564	8,486	31,050	60
1,857	849	847	2,768	486	607	704	673	1,070	762	227	23,792	9,458	33,250	66
948	480	575	2,473	613	608	727	690	1,198	809	334	23,603	9,447	33,050	72
413	194	284	1,961	654	595	736	698	1,257	837	441	22,326	8,924	31,250	78
183	50	91	1,363	678	502	696	698	1,294	856	515	20,494	8,256	28,750	84
81	8	12	795	694	329	597	634	1,318	866	546	18,041	7,959	26,000	90
32	1	1	363	704	153	472	480	1,309	828	560	14,967	7,783	22,750	96
10	0	0	121	691	49	335	286	1,182	682	564	11,533	7,617	19,150	102
2			31	500	20	196	135	902	454	529	8,314	6,586	14,900	108
0			6	227	8	96	63	562	243	448	5,528	5,222	10,750	114
			1	100	3	50	32	302	123	348	3,474	4,276	7,750	120
			0	59	0	27	15	176	76	241	2,091	3,909	6,000	126
				35		13	6	117	48	134	1,199	3,501	4,700	132
				19		6	1	80	29	60	676	3,074	3,750	138
				9		2	0	54	16	29	392	2,508	2,900	144
				3		0		35	8	14	232	2,118	2,350	150
				1				22	3	6	139	1,711	1,850	156
				0				13	0	2	81	1,369	1,450	162
								7		0	45	1,055	1,100	168
								2			22	728	750	174
								1			10	540	550	180
								0			4	296	300	186
											1	199	200	192
											0	107	107	198
												0	0	204

TABLE C-12

Meramec River Basin
Standard project flood

Drainage area sq. mi.	Station	Average rainfall inches	Re inches	Peak discharge c.f.s.
	Storm centered over entire Meramec Basin			
3,788	Eureka	11.2	6.92	223,000
1,475	Sullivan	12.1	8.06	155,000
781	Steelville	11.2	7.21	112,500
917	Byrnesville	10.3	6.42	74,900
718	DeSoto	9.9	6.08	93,100
808	Union	9.8	5.99	57,300
608	Spring Bluff	9.7	5.99	68,700
	Storm centered over Bourbeuse River			
808	Union	14.0	9.77	90,600
608	Spring Bluff	13.9	9.77	107,200
	Storm centered over Big River			
917	Byrnesville	13.4	9.17	103,500
718	DeSoto	13.1	8.98	132,600
	Storm centered over Meramec River alone			
1,475	Sullivan	12.7	8.54	164,900
781	Steelville	12.1	8.05	124,000

Initial reservoir data sheet

Reservoir	Spillway crest top of F.C. pool (m.s.l.)	Standard project storm runoff (inches)	F.C. pool Storage (ac-ft)	F.C. pool Storage (inches)	Bottom of F.C. pool (m.s.l.)	Storage (ac-ft)	Min. conservatio (100-year sedim Top elev. (m.s.l.)	Sto (ac
#2A Pine Ford	595	9.50	196,700	*4.68	561	88,300	531	11,
#5 Washington Park	706	11.88	98,110	11.50	666	49,055	618	5,
#40 Virginia Mines	577	11.37	139,730	10.92	556	110,270	527	8,
#9 Irondale	860	11.68	106,160	11.37	832	54,840	796	5,
#17 Meramec Park	701	8.46	581,560	7.23	667	418,440	600	18,
#27 Salem	1,008	11.68	104,965	11.25	973	56,185	928	5,
#29 Union	651	9.94	355,630	8.84	616	172,370	567	11,
		50-Yr.Runoff						
I-14	881	4.98	27,535	4.61	847	7,865	837	3,
I-15A	834	4.96	29,590	4.55	806	8,410	799	4,
I-21	904	5.35	6,470	5.16	887	2,150	885	1,
I-23	941	5.20	9,520	5.01	919	3,170	914	2,
I-26	1,026	5.30	7,305	5.07	1,015	18,695	959	1,
I-28	1,112	5.20	11,760	5.01	1,101	14,240	1,079	2,
I-30	790	5.38	5,480	5.19	774	1,620	771	1,
I-32	718	5.12	15,785	4.93	703	10,215	689	3,
I-33A	777	5.18	13,845	4.99	764	12,155	743	2,
I-35A	786	5.09	18,040	4.90	772	7,960	756	3,
I-38	857	4.96	29,585	4.58	837	9,415	830	4,
I-41	874	5.23	7,745	5.04	853	2,580	850	1,
**H-3	630	-	2,700	-	616	900	616	
H-4	680	-	2,500	-	656	800	656	
H-5A	543	-	1,000	-	525	300	525	
H-6	530	-	2,900	-	513	1,000	513	
H-8	723	-	5,000	-	699	1,700	697	1,
H-9	950	-	2,300	-	931	800	931	
H-10A	982	-	1,300	-	961	500	961	
H-11A	798	-	3,600	-	778	1,200	776	1,
H-13A	824	-	5,000	-	810	1,700	808	1,
H-25	1,061	-	3,900	-	1,035	1,300	1,034	1,
H-31	882	-	1,700	-	871	600	871	
H-40	671	-	--	-	671	900	661	

* To be operated jointly with #5 and #9.
** All H-Site values are approximate. Final determination by S.C.S.
*** To be determined by S.C.S.
**** Approximate Elevation.

2

et

age (ft)	Min. conservation pool (100-year sediment cap) Top elev. (m.s.l.)	Storage (ac-ft)	Net storage joint-use pool (ac-ft)	Total storage (ac-ft)	Top dam elevation (m.s.l.)	Surcharge (ft.)
300	531	11,986	76,314	285,000	637	37.0
055	618	5,588	43,467	147,165	737	26.0
,270	527	8,974	101,296	250,000	610	28.0
,840	796	5,832	49,008	161,000	887	22.0
,440	600	18,251	400,189	1,000,000	736	30.0
,185	928	5,985	50,200	161,150	1,039	26.0
,370	567	11,900	160,470	528,000	682	26.0
,865	837	3,942	3,923	35,400	916	30.0
,410	799	4,755	3,655	38,000	867	28.0
,150	885	1,637	513	8,620	916	7.0
,170	914	2,144	1,026	12,690	965	19.0
,695	959	1,786	16,909	26,000	1,046	15.0
,240	1,079	2,467	11,773	26,000	1,124	7.0
,620	771	1,472	148	7,100	811	16.0
,215	689	3,013	7,202	26,000	728	5.0
,155	743	2,733	9,422	26,000	797	15.0
,960	756	3,298	4,662	26,000	809	18.0
,415	830	4,715	4,700	39,000	880	18.0
,580	850	1,868	712	10,325	898	19.0
900	616	899	--	3,600	640 ****	***
800	656	868	--	3,300	690 ****	***
300	525	306	--	1,300	553 ****	***
,000	513	976	24	3,900	540 ****	***
,700	697	1,390	310	6,700	733 ****	***
800	931	823	--	3,100	960 ****	***
500	961	568	--	1,800	992 ****	***
,200	776	1,095	105	4,800	808 ****	***
,700	808	1,405	295	6,700	834 ****	***
,300	1,034	1,165	135	5,200	1,071 ****	***
600	871	673	--	2,300	892 ****	***
900	661	511	389	900	681 ****	***

TABLE C-14
R Mar 64

Final reservoir data sheet

Reservoir	Spillway crest	Flood control storage (ac-ft)	Frequency of protection (years)	Normal pool elevation (m.s.l.)	Joint-use storage (ac-ft)	Min. conservation (100-year sediment Elevation (m.s.l.)	Stor (ac-
#2A Pine Ford	595	196,700	100	561	88,300	531	12,
#5 Washington Park	706	-	-	706	147,200	618	5,
#40 Virginia Mines	556	-	-	556	110,300	527	9,
#9 Irondale	860	23,900	10	855	137,100	796	5,
#17 Meramec Park	701	581,600	Std. Proj.	667	418,400	600	18,
#27 Salem	1,008	30,000	20	1,000	131,200	928	6,
#29 Union	651	355,600	Std. Proj.	616	172,400	567	11,
I-14	881	27,500	50	847	7,900	837	4,
I-15A	834	29,600	50	806	8,400	799	4,
I-21	904	6,300	50	887	2,300	885	1,
I-23	941	-	-	941	12,700	914	2,
I-26	1,026	4,600	20	1,019	21,400	959	1,
I-28	1,112	11,800	50	1,101	14,200	1,079	2,
I-30	790	2,700	10	782	4,400	771	1,
I-32	718	-	-	718	26,000	689	3,
I-33A	777	-	-	777	26,000	743	2,
I-35A	786	-	-	786	26,000	756	3,
I-38	857	29,600	50	837	9,400	830	4,
I-41	874	7,700	50	853	2,600	850	1,
H-3	629	1,850	50	618	900	615	
H-4	673	-	-	673	2,080	650	
H-5A	549	640	50	537	310	535	
H-6	536	-	-	536	2,760	521	
H-8	717	2,840	20	706	3,120	692	1,
H-9	948	1,430	50	935	810	933	
H-10A	1,006	670	50	997	570	994	
H-11A	818	1,880	50	806	1,170	802	
H-13A	811	4,170	50	794	1,410	793	1,
H-25	1,044	700	10	1,038	1,960	1,027	
H-31	885	-	-	885	1,760	874	
H-40	675	-	-	675	900	663	

2

voir data sheet

se ()	Min. conservation pool (100-year sediment cap) Elevation (m.s.l.)	Storage (ac-ft)	Net storage joint-use pool (ac-ft)	Total storage (ac-ft)	Top of dam (m.s.l.)	Maximum surcharge (feet)
00	531	12,000	76,300	285,000	637	37
00	618	5,600	141,600	147,200	737	26
00	527	9,000	101,300	110,300	592	31
00	796	5,800	131,300	161,000	887	22
00	600	18,200	400,200	1,000,000	736	30
00	928	6,000	125,200	161,000	1,039	26
00	567	11,900	160,500	528,000	682	26
00	837	4,000	3,900	35,400	916	30
00	799	4,800	3,600	38,000	867	28
00	885	1,600	700	8,600	916	7
00	914	2,100	10,600	12,700	965	19
00	959	1,800	19,600	26,000	1,046	15
00	1,079	2,500	11,700	26,000	1,124	7
00	771	1,500	2,900	7,100	811	16
00	689	3,000	23,000	26,000	728	5
00	743	2,700	23,300	26,000	797	15
00	756	3,300	22,700	26,000	809	18
00	830	4,700	4,700	39,000	880	18
00	850	1,900	700	10,300	898	19
00	615	670	230	2,750	635	6.0
80	650	650	1,430	2,080	683	9.0
10	535	230	80	950	555	5.4
60	521	730	2,030	2,760	543	6.6
20	692	1,040	2,080	5,960	723	5.3
10	933	620	190	2,240	955	7.0
70	994	430	140	1,240	1,015	7.8
70	802	820	350	3,050	824	6.0
10	793	1,060	350	5,580	817	6.8
60	1,027	870	1,090	2,660	1,054	8.7
60	874	510	1,250	1,760	895	6.4
00	663	380	520	900	685	8.9

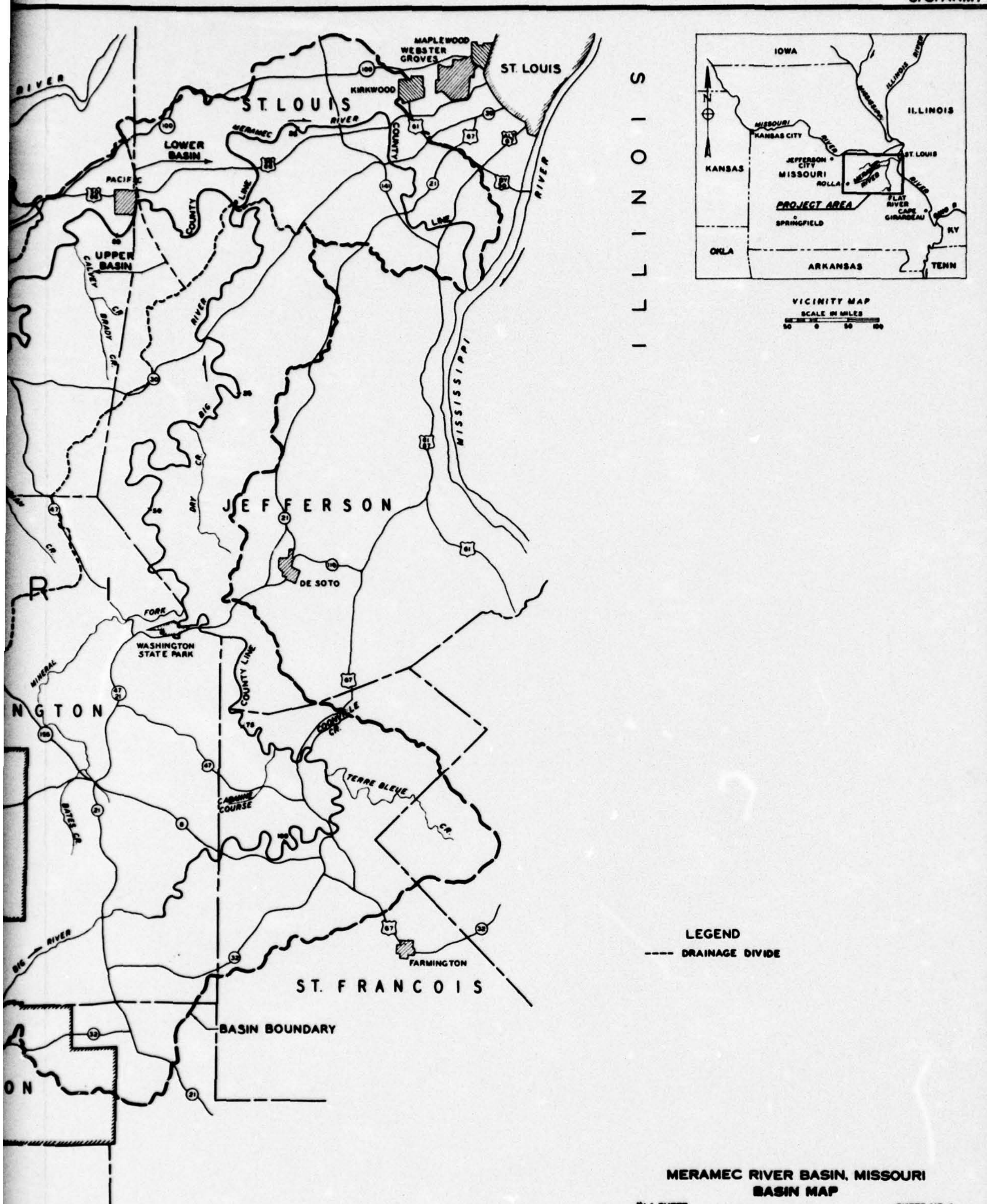
TABLE C-14A
R Mar 64

Meramec River Basin
Sedimentation requirements at reservoirs

Reservoir	Drainage area uncontrolled by upstream dams (sq. mi.)	100-yr. accumulation - ac.ft.
2A Pine Ford	420.5	11,986
5 Washington Park	151.8	5,588
9 Irondale	161.2	5,832
40 Virginia Mines	221.9	8,974
17 Meramec Park	775.0	18,251
27 Salem	175.0	5,985
29 Union	391.5	11,900
I-14	85.0	3,942
I-15A	122.0	4,755
I-21	23.5	1,637
I-23	35.6	2,144
I-26	27.0	1,786
I-28	44.0	2,467
I-30	19.8	1,472
I-32	60.0	3,013
I-33A	52.0	2,733
I-35A	69.0	3,298
I-38	121.0	4,715
I-41	28.8	1,868

TABLE C-15

CORPS OF ENGINEERS



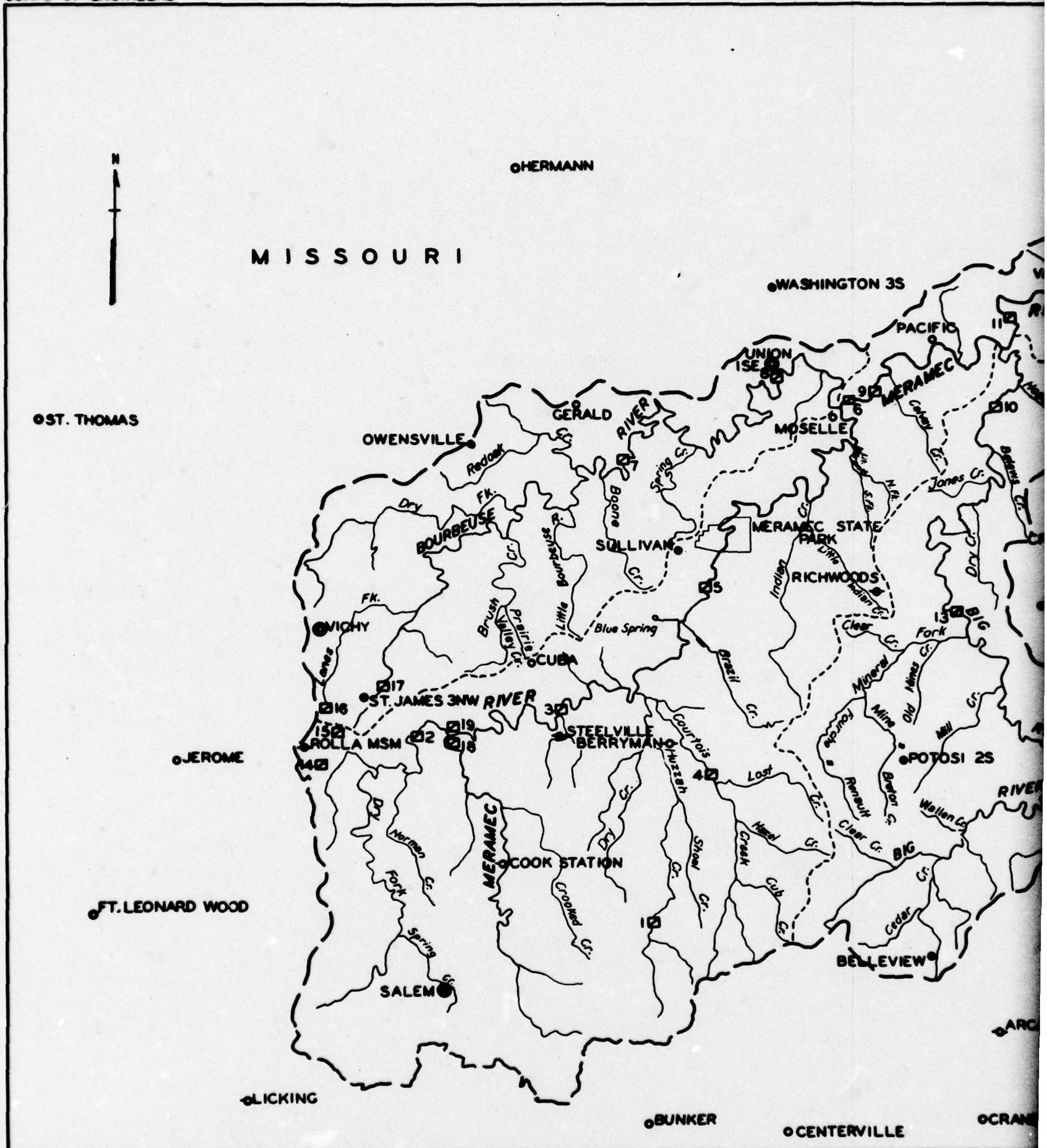
MERAMEC RIVER BASIN, MISSOURI
BASIN MAP

IN 1 SHEET — SHEET NO. 1

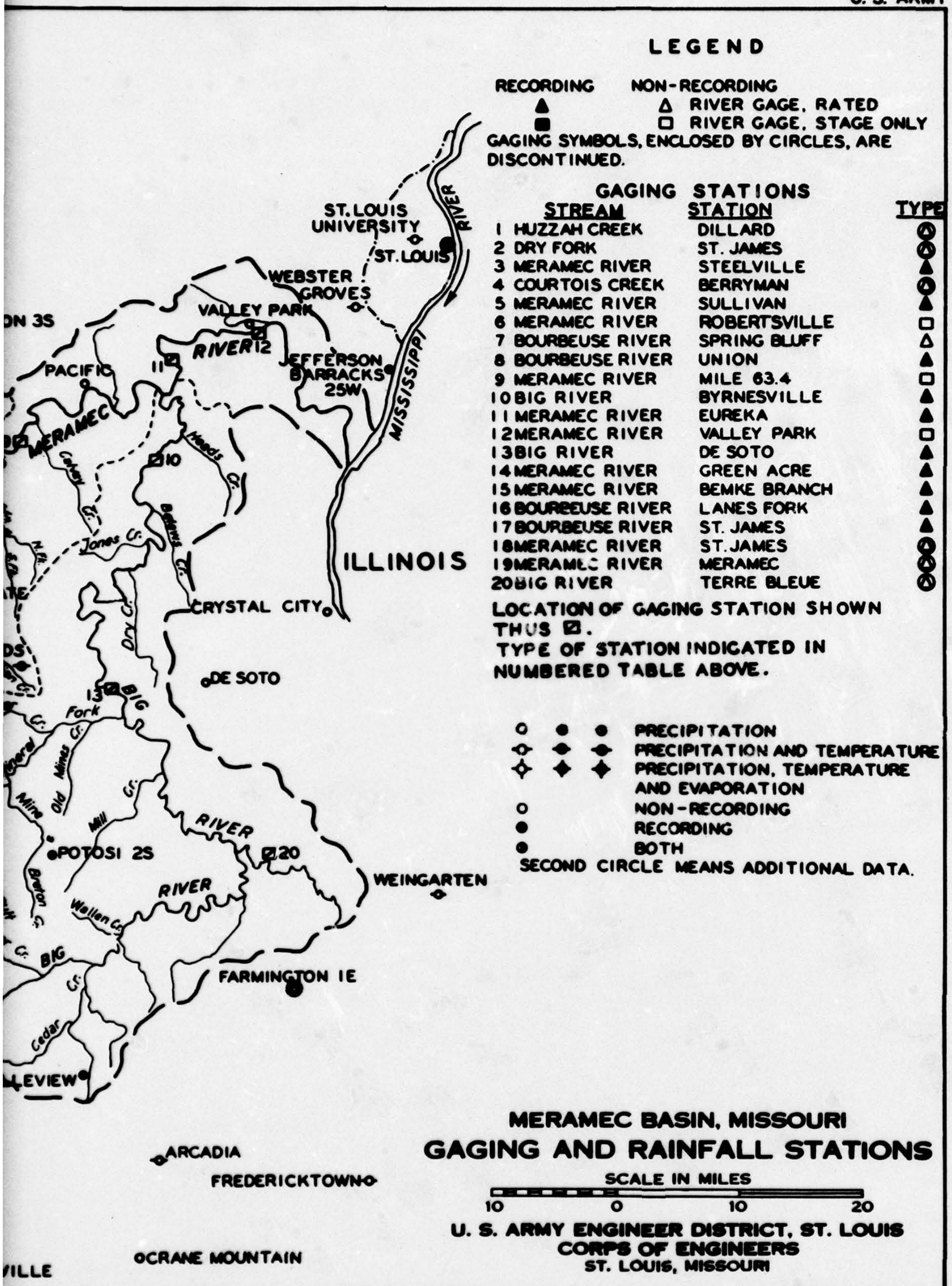
SCALE IN MILES

U. S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI
JANUARY 1984

PLATE C-1


MISSOURI
N
HERMANN
WASHINGTON 3S
PACIFIC
UNION
GERALD
OWENSVILLE
ST. THOMAS
MOSELLE
MERAMEC
SULLIVAN
MERAMEC STATE PARK
RICHWOODS
BOURBEUSE
VICHY
CUBA
ST. JAMES 3NW
RIVER
STEELVILLE
BERRYMAN
ROLLA MSM
JEROME
POTOSI 2S
COOK STATION
FT. LEONARD WOOD
BELLEVIEW
SALEM
LICKING
BUNKER
CENTERVILLE
Blue Spring
BIG

U. S. ARMY



LEGEND

RECORDING ▲ ■ — NON-RECORDING △ RIVER GAGE, RATED; □ RIVER GAGE, STAGE ONLY

GAGING SYMBOLS, ENCLOSED BY CIRCLES, ARE DISCONTINUED.

GAGING STATIONS

	STREAM	STATION	TYPE
1	HUZZAH CREEK	DILLARD	▲ (circled)
2	DRY FORK	ST. JAMES	▲ (circled)
3	MERAMEC RIVER	STEELVILLE	▲
4	COURTOIS CREEK	BERRYMAN	▲ (circled)
5	MERAMEC RIVER	SULLIVAN	▲
6	MERAMEC RIVER	ROBERTSVILLE	□
7	BOURBEUSE RIVER	SPRING BLUFF	△
8	BOURBEUSE RIVER	UNION	▲
9	MERAMEC RIVER	MILE 63.4	□
10	BIG RIVER	BYRNESVILLE	▲
11	MERAMEC RIVER	EUREKA	▲
12	MERAMEC RIVER	VALLEY PARK	□
13	BIG RIVER	DE SOTO	▲
14	MERAMEC RIVER	GREEN ACRE	▲
15	MERAMEC RIVER	BEMKE BRANCH	▲
16	BOURBEUSE RIVER	LANES FORK	▲
17	BOURBEUSE RIVER	ST. JAMES	▲
18	MERAMEC RIVER	ST. JAMES	▲ (circled)
19	MERAMEC RIVER	MERAMEC	▲ (circled)
20	BIG RIVER	TERRE BLEUE	△ (circled)

LOCATION OF GAGING STATION SHOWN THUS ⊠.
TYPE OF STATION INDICATED IN NUMBERED TABLE ABOVE.

○	●	●	PRECIPITATION
○	●	●	PRECIPITATION AND TEMPERATURE
○	●	●	PRECIPITATION, TEMPERATURE AND EVAPORATION
○			NON-RECORDING
●			RECORDING
●			BOTH

SECOND CIRCLE MEANS ADDITIONAL DATA.

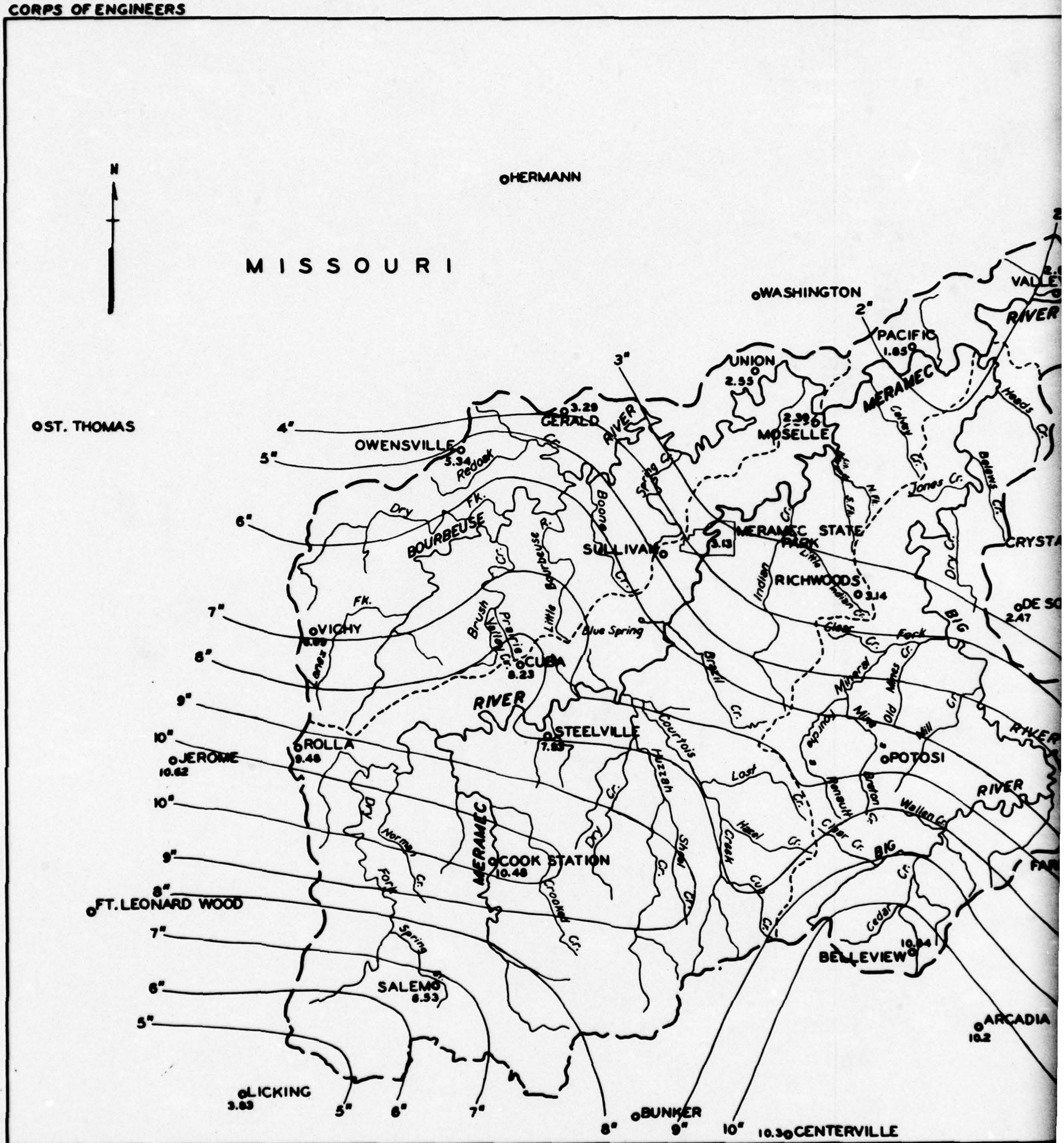
MERAMEC BASIN, MISSOURI
GAGING AND RAINFALL STATIONS

SCALE IN MILES
10 0 10 20

U. S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

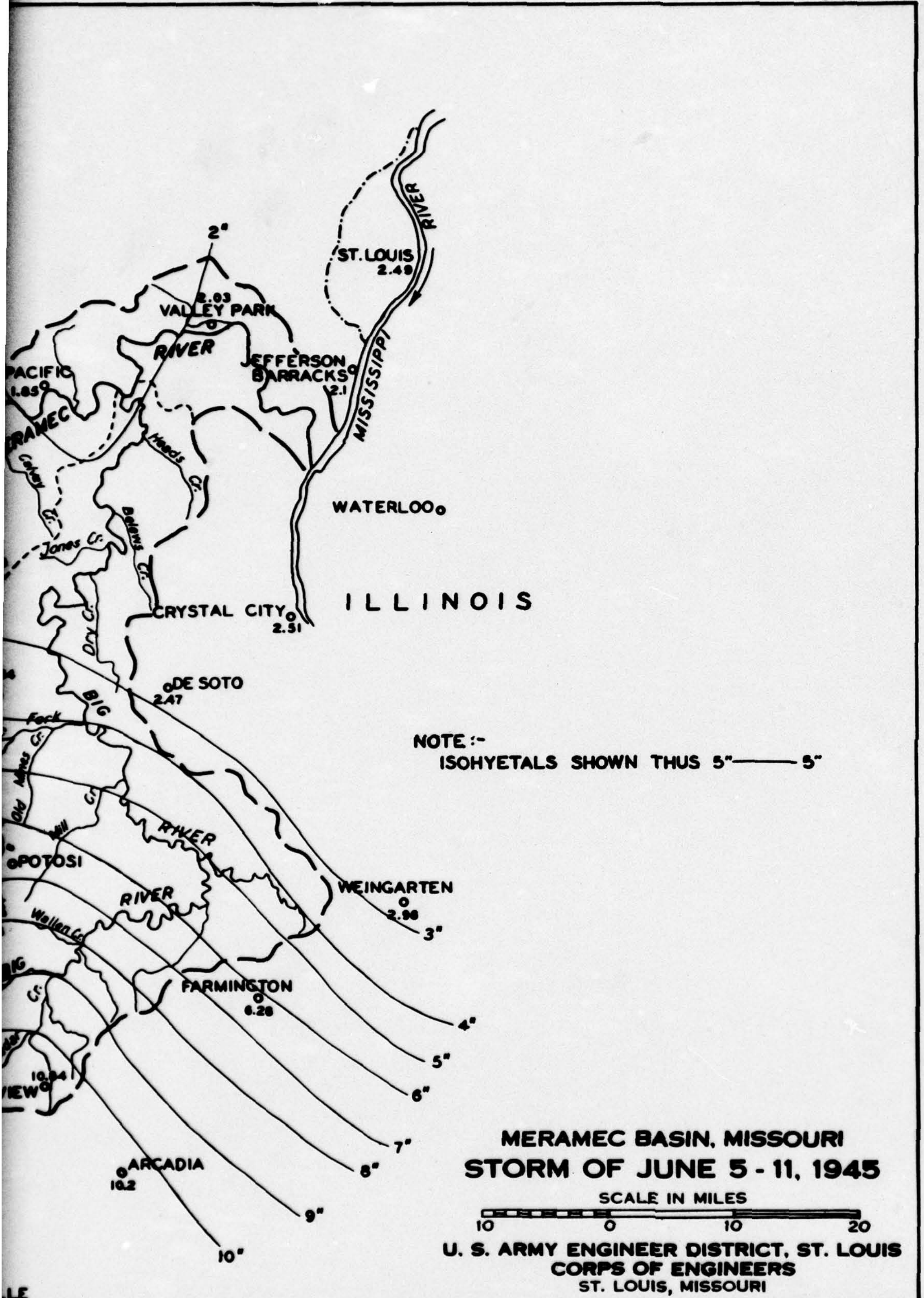
PLATE C-2

CORPS OF ENGINEERS



2

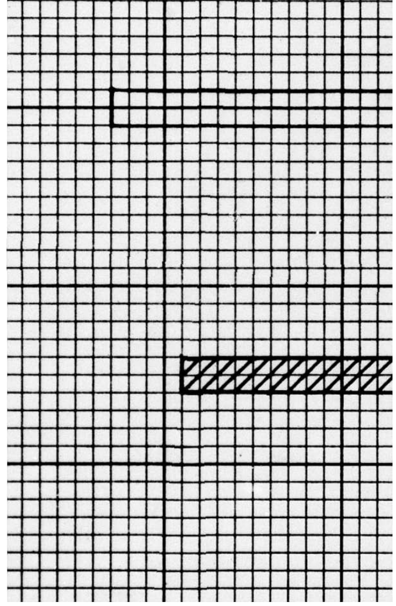
U.S. ARMY

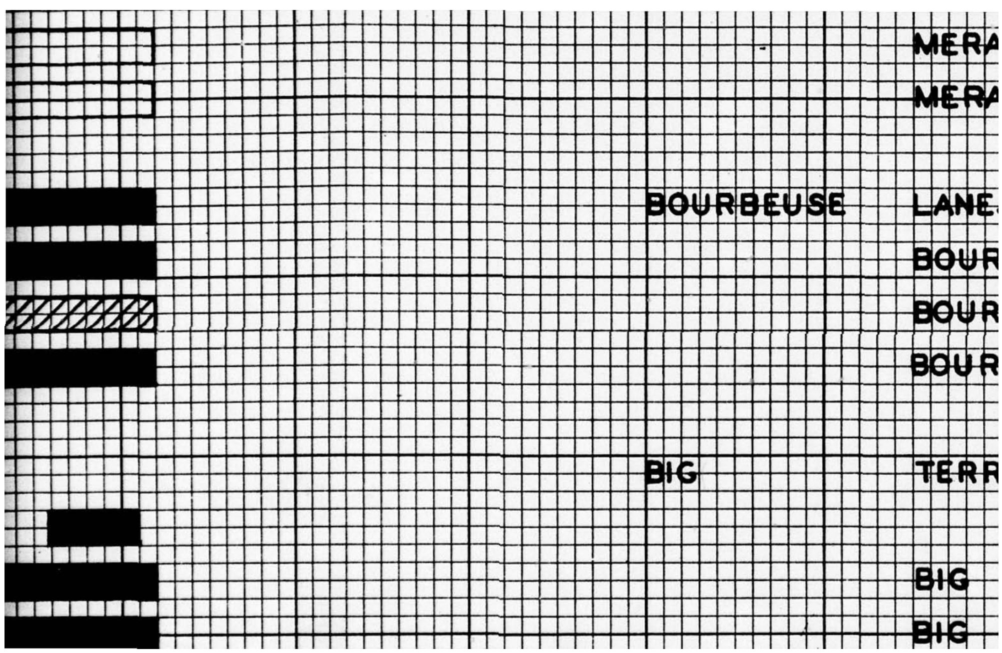


MERAMEC BASIN, MISSOURI
STORM OF JUNE 5 - 11, 1945

U. S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

PLATE C-3




MERA
MERA
BOURBEUSE
LANE
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BIG
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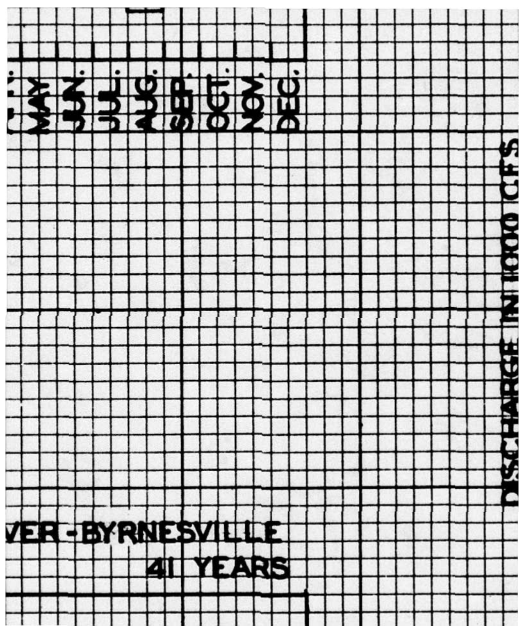
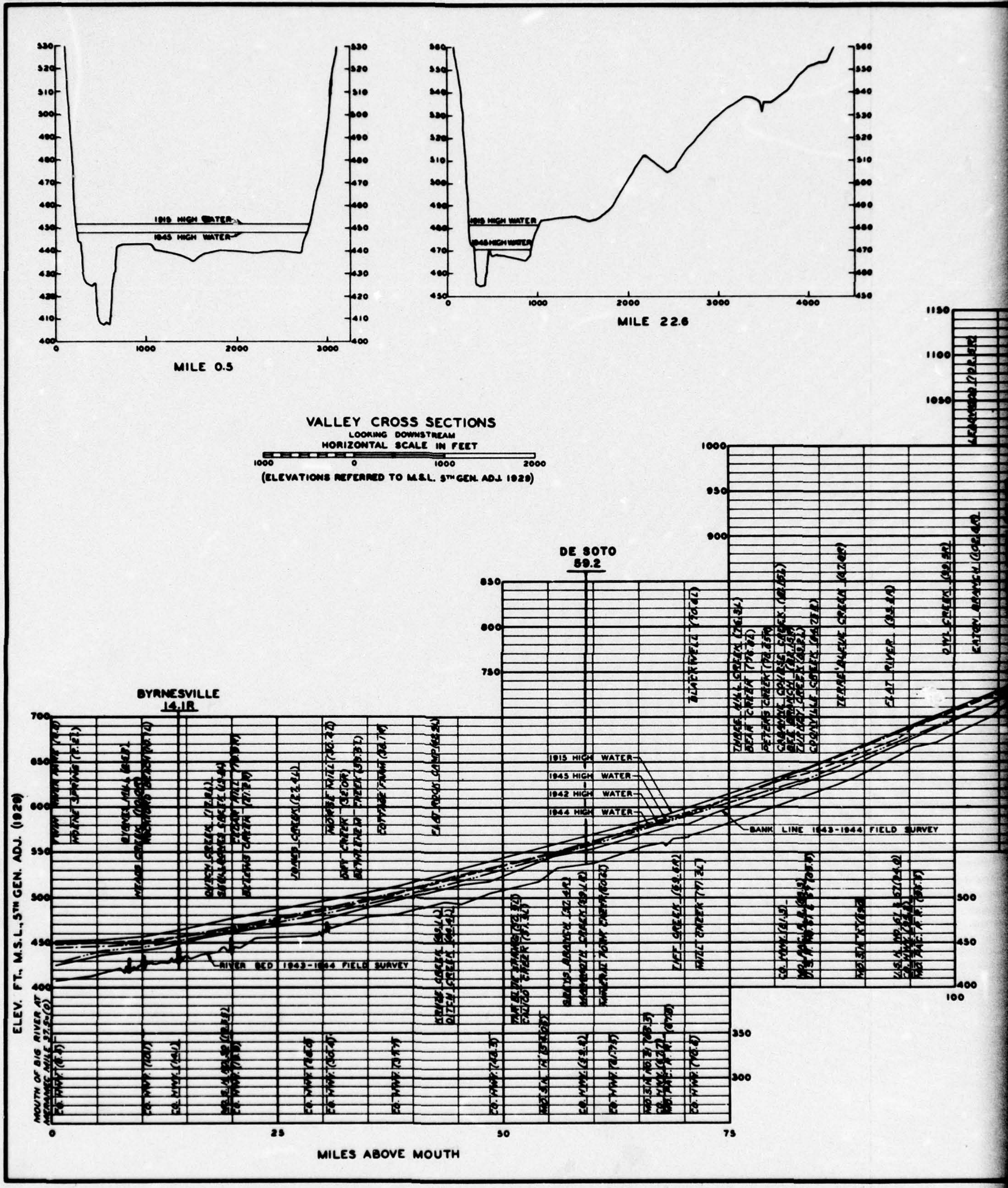
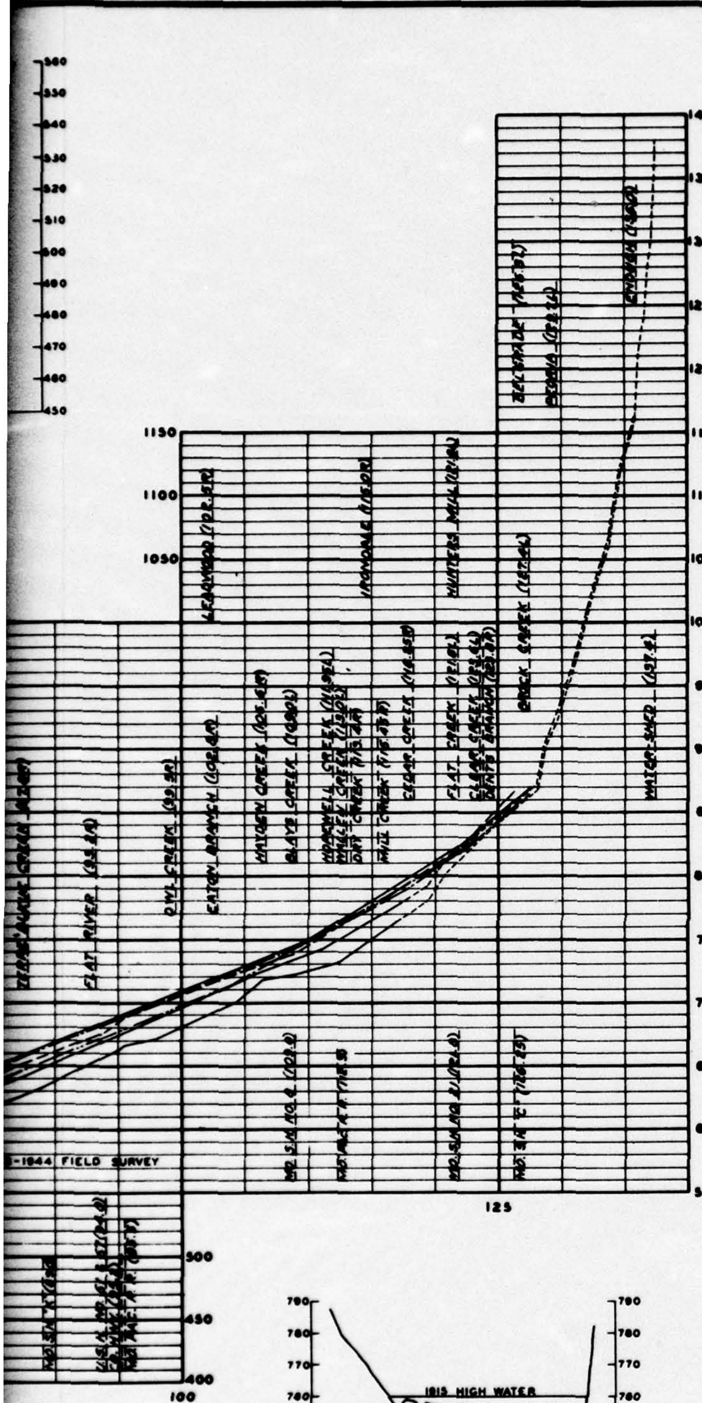
BIG

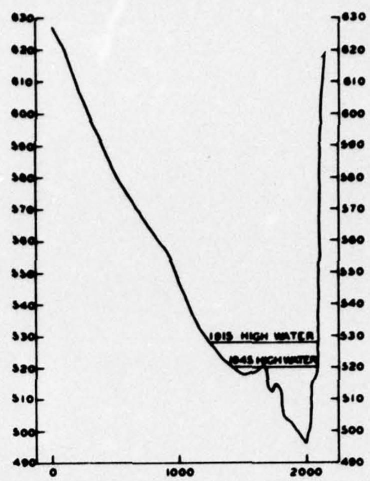

MAY
JUN.
JUL.
AUG.
SEP.
OCT.
NOV.
DEC.
DISCHARGE IN 1000 CFS
VER - BYRNESVILLE
41 YEARS

0

JAN. FEB. MAR. APR. MAY JUN. JUL. AUG. SEP. OCT. NOV. DEC.


MILE 0.5
MILE 22.6
1915 HIGH WATER
1945 HIGH WATER
VALLEY CROSS SECTIONS
LOOKING DOWNSTREAM
HORIZONTAL SCALE IN FEET
(ELEVATIONS REFERRED TO M.S.L. 5TH GEN. ADJ. 1929)
BYRNESVILLE
14.1R
DE SOTO
59.2
1942 HIGH WATER
1944 HIGH WATER
BANK LINE 1943-1944 FIELD SURVEY
RIVER BED 1943-1944 FIELD SURVEY
ELEV. FT., M.S.L., 5TH GEN. ADJ. (1929)
MILES ABOVE MOUTH
FLAT RIVER
OWL CREEK
EATON BRANCH
BLACKWELL
JONES CREEK
COTTAGE FARM
MILL CREEK
TIFF CREEK
PETERS CREEK
TERRE BLEUE CREEK





MILE 44.0

NOTES

Data relating to the location of towns, Federal, state and county highway bridges, springs and tributaries were secured from U. S. Geological Survey maps and from county highway maps prepared by the Missouri State Highway Department. Gage locations were obtained from the records of the Missouri Geological Survey and Water Resources, and the U. S. Weather Bureau.

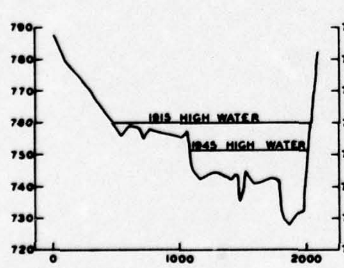
Bank and river bed profiles from the mouth to mile 117.4 are based on field data secured by survey parties under the direction of this office. The portions of the profiles between mile 117.4 and the source of the stream, indicated by dashed lines, represent information secured from maps but not checked by field surveys.

Flood profiles were plotted from gage records supplemented by field observations of high water marks by the U. S. Engineer Department.

The designations R and L applied to locations refer to right or left bank looking downstream.

The abbreviation Mo. S.H. indicates ownership of bridge by the Missouri State Highway Department.

Stream gage locations are written horizontally above the profile.



MILE 111.0

MERAMEC BASIN, MISSOURI

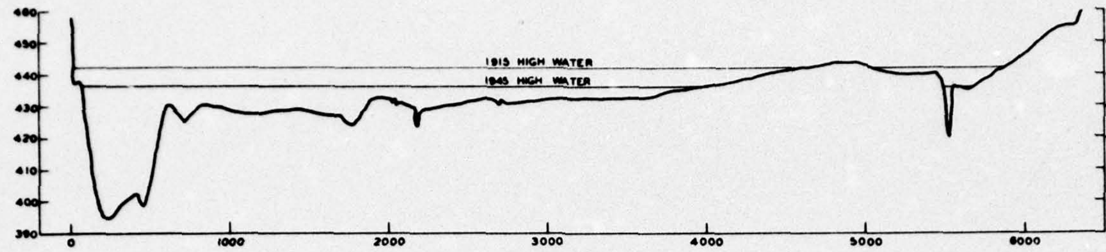
BIG RIVER

RIVER PROFILES

IN 1 SHEET — SHEET NO. 1

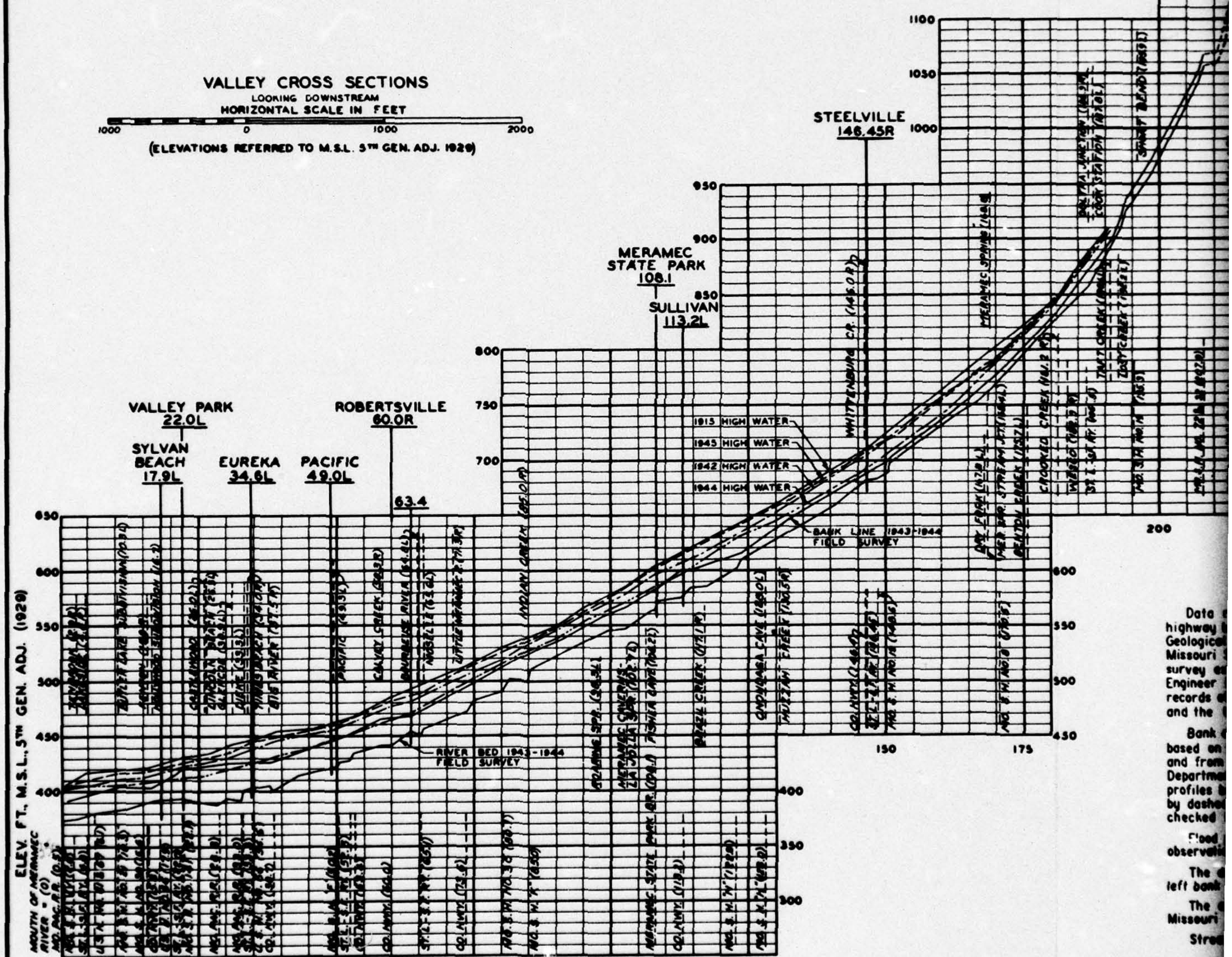
SCALE AS SHOWN

U. S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI



MILE 30.7
NEAR TIMES BEACH

VALLEY CROSS SECTIONS
LOOKING DOWNSTREAM
HORIZONTAL SCALE IN FEET
1000 0 1000 2000
(ELEVATIONS REFERRED TO M.S.L. 5TH GEN. ADJ. 1929)



Data
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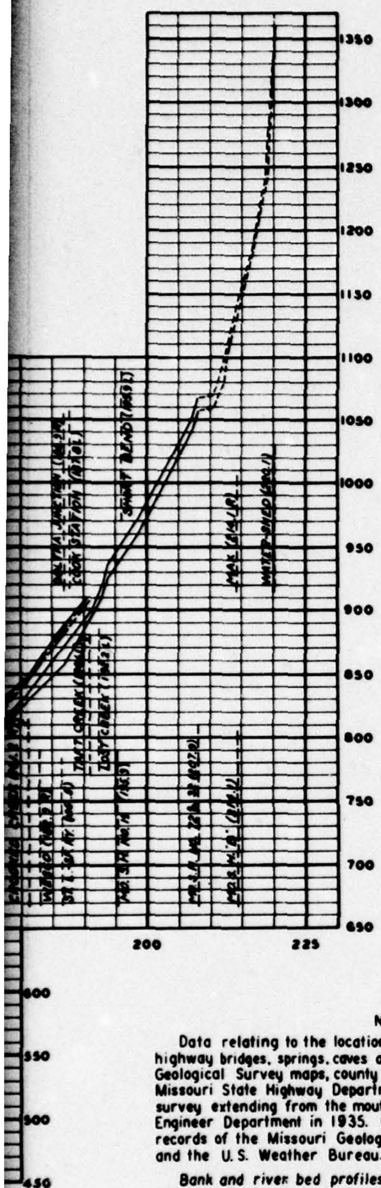
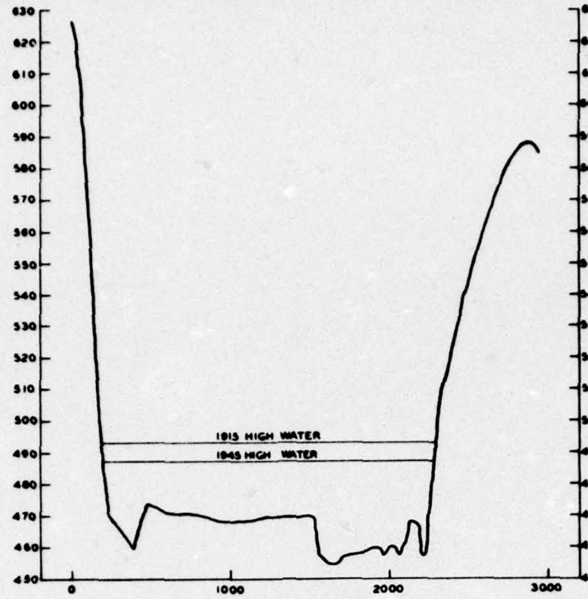
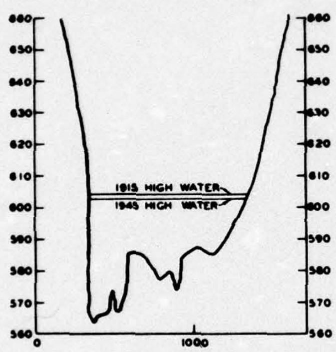
U. S. ARMY

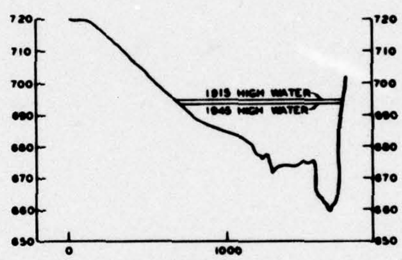




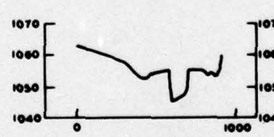
MILE 63.4
NEAR MOUTH OF BOURBEUSE



MILE 107.55
MERAMEC STATE PARK



MILE 142.2
NEAR BIRDS NEST



MILE 207.0
NEAR INDIAN TRAIL STATE PARK

NOTES

Data relating to the location of towns, Federal, state and county highway bridges, springs, caves and tributaries were secured from U.S. Geological Survey maps, county highway maps prepared by the Missouri State Highway Department and from the records of a field survey extending from the mouth to mile 22.3 completed by the U.S. Engineer Department in 1935. Gage locations were obtained from the records of the Missouri Geological Survey and Water Resources and the U.S. Weather Bureau.

Bank and river bed profiles from the mouth to mile 192.8 are based on field survey data collected by the U.S. Engineer Department and from mile 192.8 to mile 208.2 on field data secured by U.S. Department of Agriculture survey parties. The portions of the profiles between mile 208.2 and the source of the stream, indicated by dashed lines, represent information secured from maps but not checked by field surveys.

Flood profiles were plotted from gage records supplemented by field observations of high water marks by the U.S. Engineer Department.

The designations R and L applied to locations refer to right or left bank looking downstream.

The abbreviation Mo. S.H. indicates ownership of bridge by Missouri State Highway Department.

Stream gage locations are written horizontally above the profile.

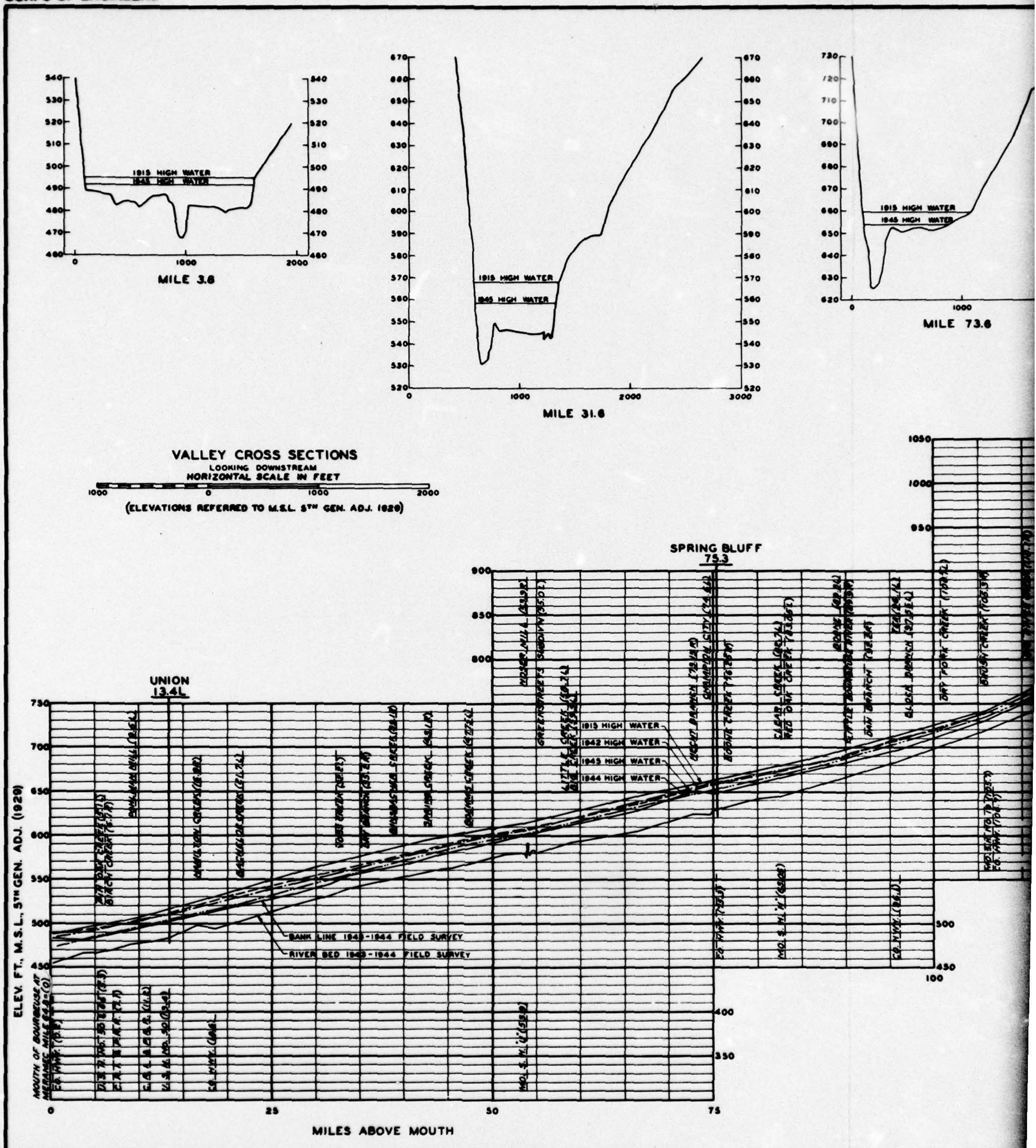
MERAMEC BASIN, MISSOURI
MERAMEC RIVER
RIVER PROFILES

IN 1 SHEET — SHEET NO. 1

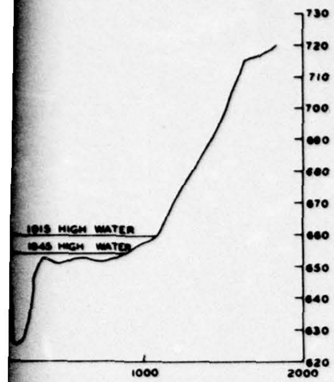
SCALE AS SHOWN

U. S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

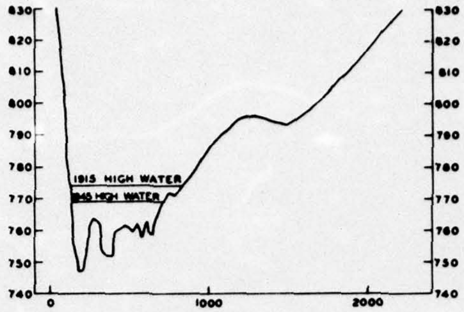
PLATE C-7



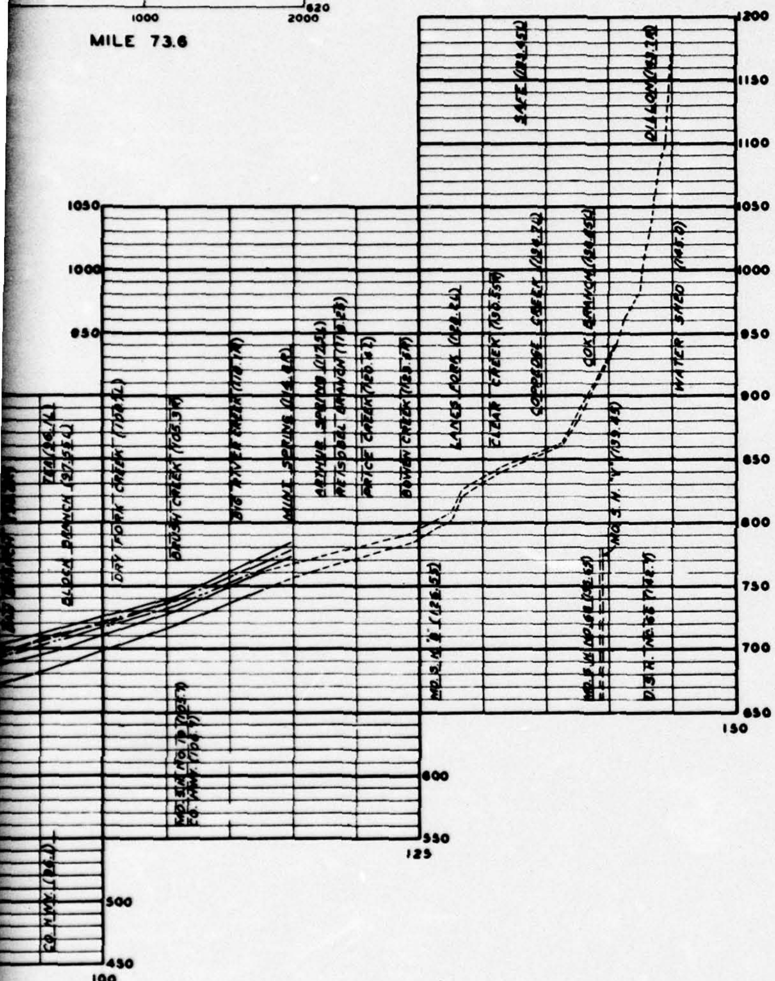
MILE 3.6
MILE 31.6
MILE 73.6
1915 HIGH WATER
1945 HIGH WATER
VALLEY CROSS SECTIONS
LOOKING DOWNSTREAM
HORIZONTAL SCALE IN FEET
(ELEVATIONS REFERRED TO M.S.L. 5TH GEN. ADJ. 1929)
SPRING BLUFF
75.3
UNION
13.4L
1915 HIGH WATER
1942 HIGH WATER
1943 HIGH WATER
1944 HIGH WATER
BANK LINE 1943-1944 FIELD SURVEY
RIVER BED 1943-1944 FIELD SURVEY
ELEV. FT., M.S.L., 5TH GEN. ADJ. (1929)
MILES ABOVE MOUTH



MILE 73.6



MILE 112.7



NOTES

Data relating to the location of towns, Federal, state and county highway bridges, springs and tributaries were secured from U. S. Geological Survey maps and from county highway maps prepared by the Missouri State Highway Department. Gage locations were obtained from the records of the Missouri Geological Survey and Water Resources and the U. S. Weather Bureau.

Bank and river bed profiles from the mouth to mile 112.7 are based on field data secured by survey parties under the direction of this office. The portions of the profiles between mile 112.7 and the source of the stream, indicated by dashed lines, represent information secured from maps but not checked by field surveys.

Flood profiles were plotted from gage records, supplemented by field observations of high water marks by the U. S. Engineer Department.

The designations R and L applied to locations refer to right or left bank looking downstream.

The abbreviation Mo. S. H. indicates ownership of bridge by Missouri State Highway Department.

Stream gage locations are written horizontally above the profile.

MERAMEC BASIN, MISSOURI

BOURBEUSE RIVER

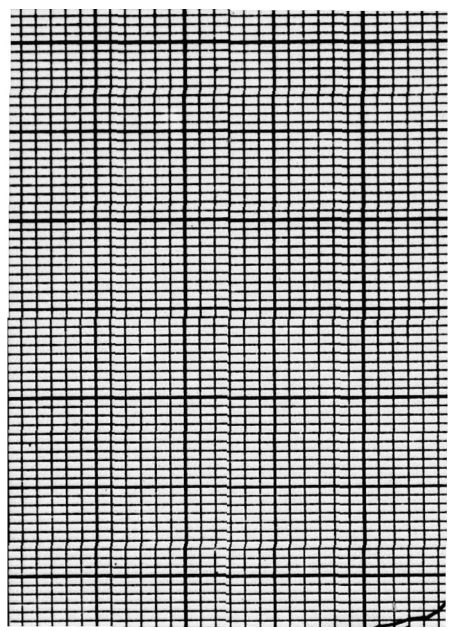
RIVER PROFILES

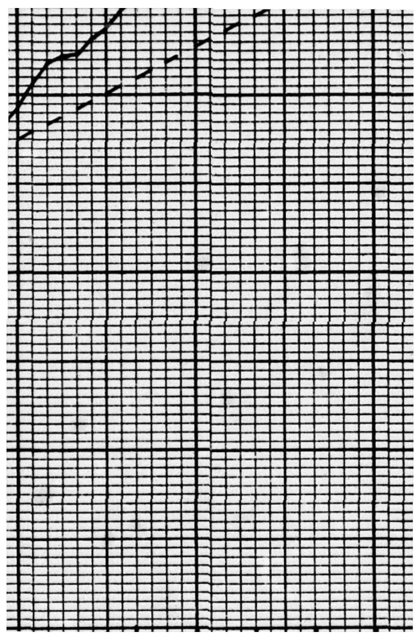
IN 1 SHEET | SHEET NO. 1

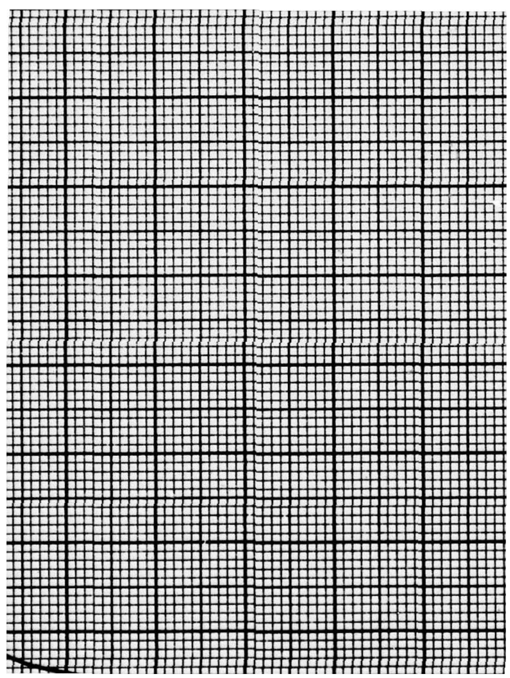
SCALE AS SHOWN

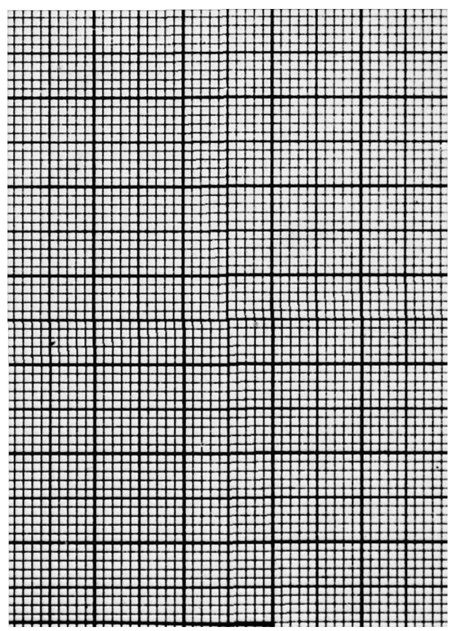
U. S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS MISSOURI

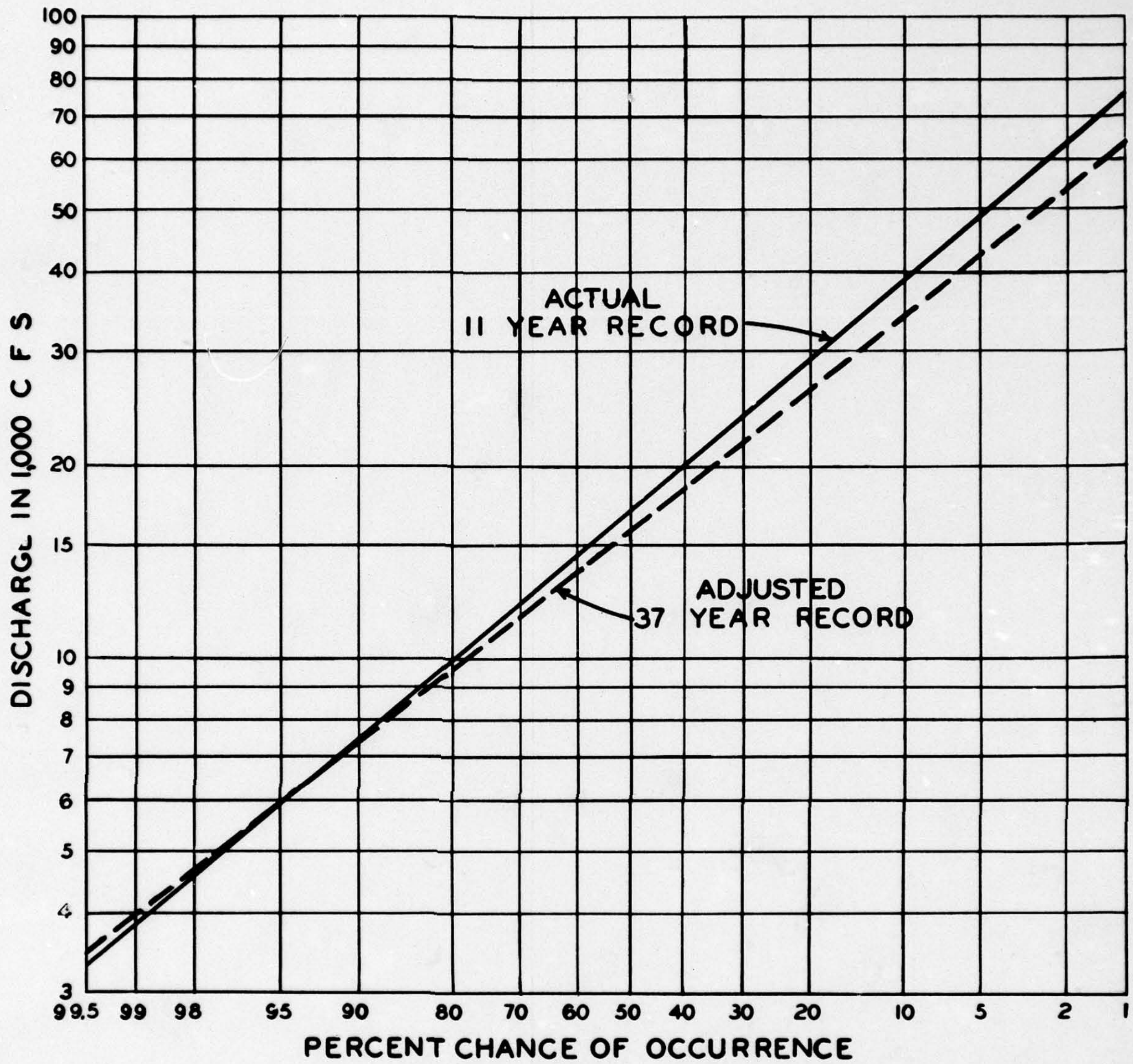
PLATE C-8









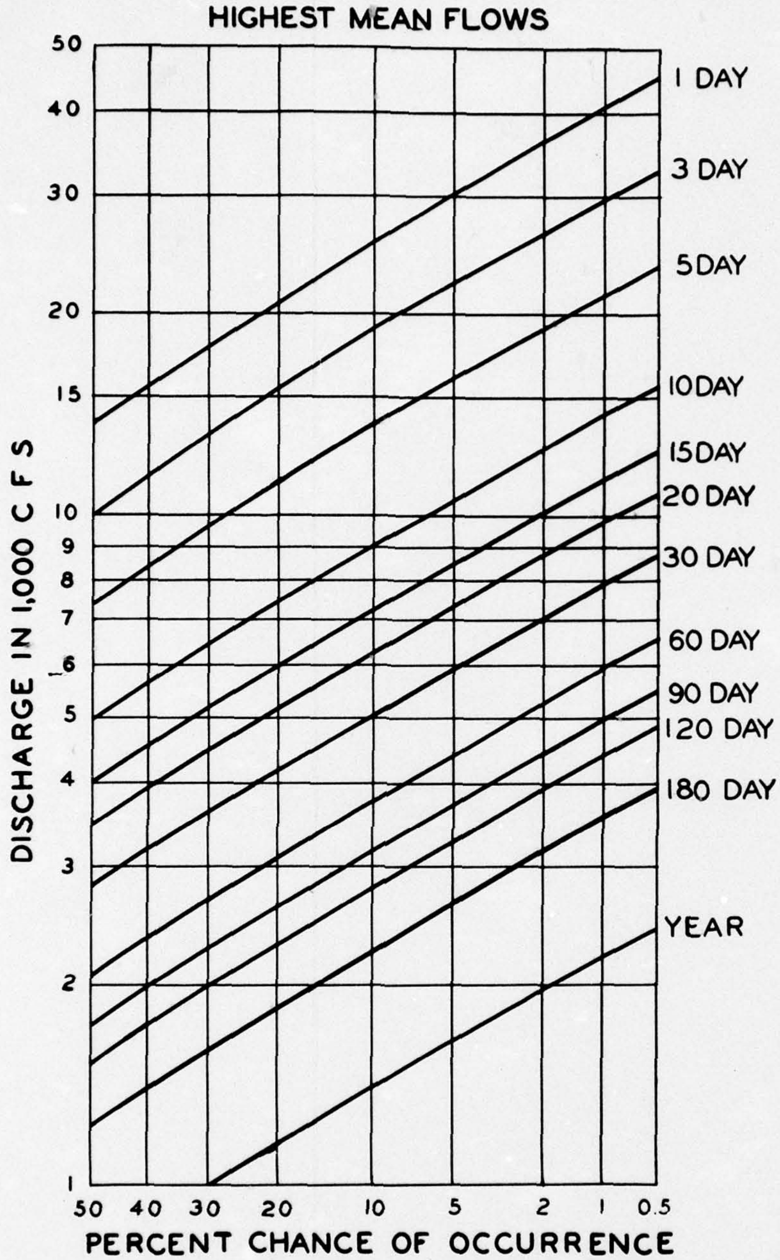


MERAMEC RIVER BASIN, MISSOURI

BIG RIVER AT DESOTO, MO.-MAXIMUM ANNUAL DISCHARGE FREQUENCY

SCALE AS SHOWN

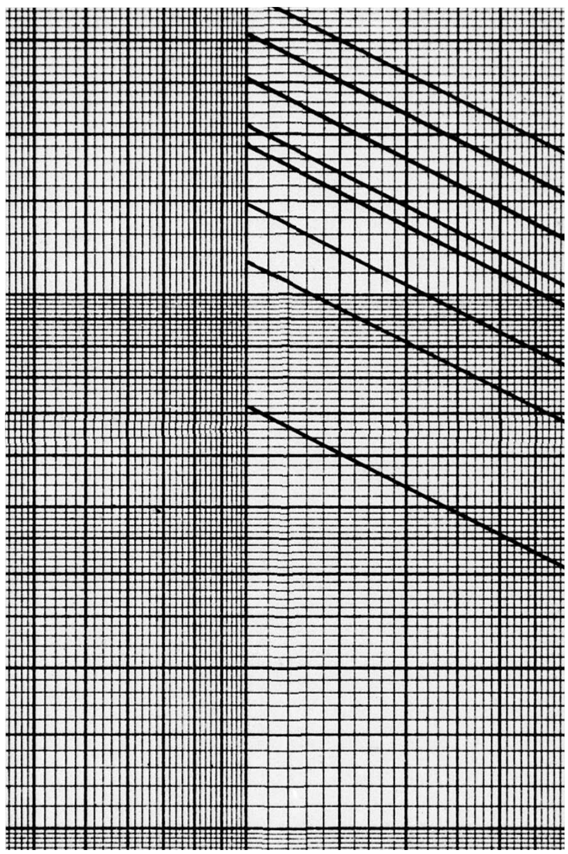
U. S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

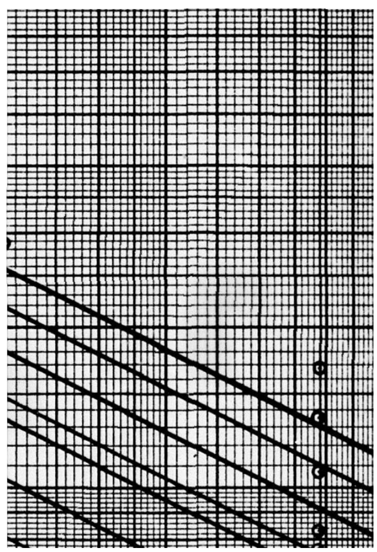


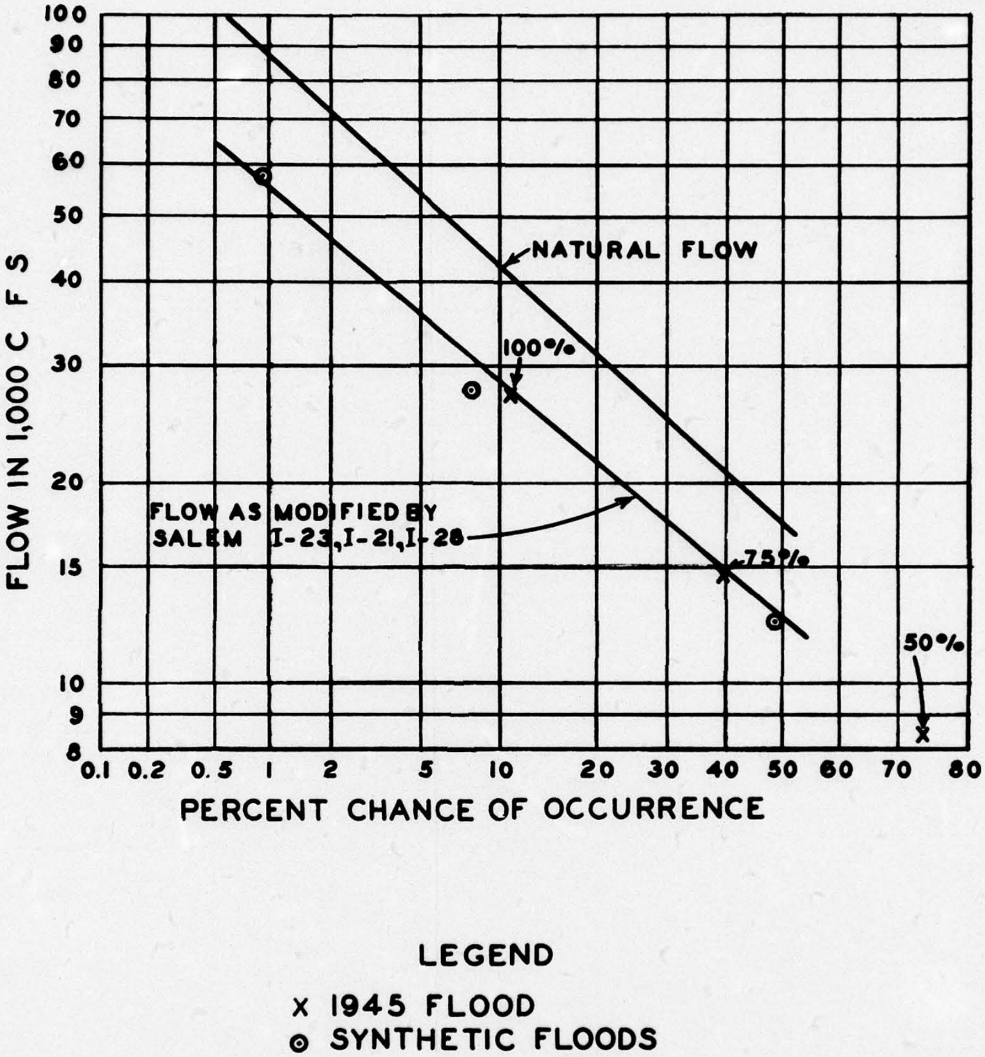
MERAMEC RIVER BASIN, MISSOURI
BIG RIVER AT BYRNESVILLE, MO.-HIGHEST ANNUAL MEAN FLOW FREQUENCY

SCALE AS SHOWN

U. S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI





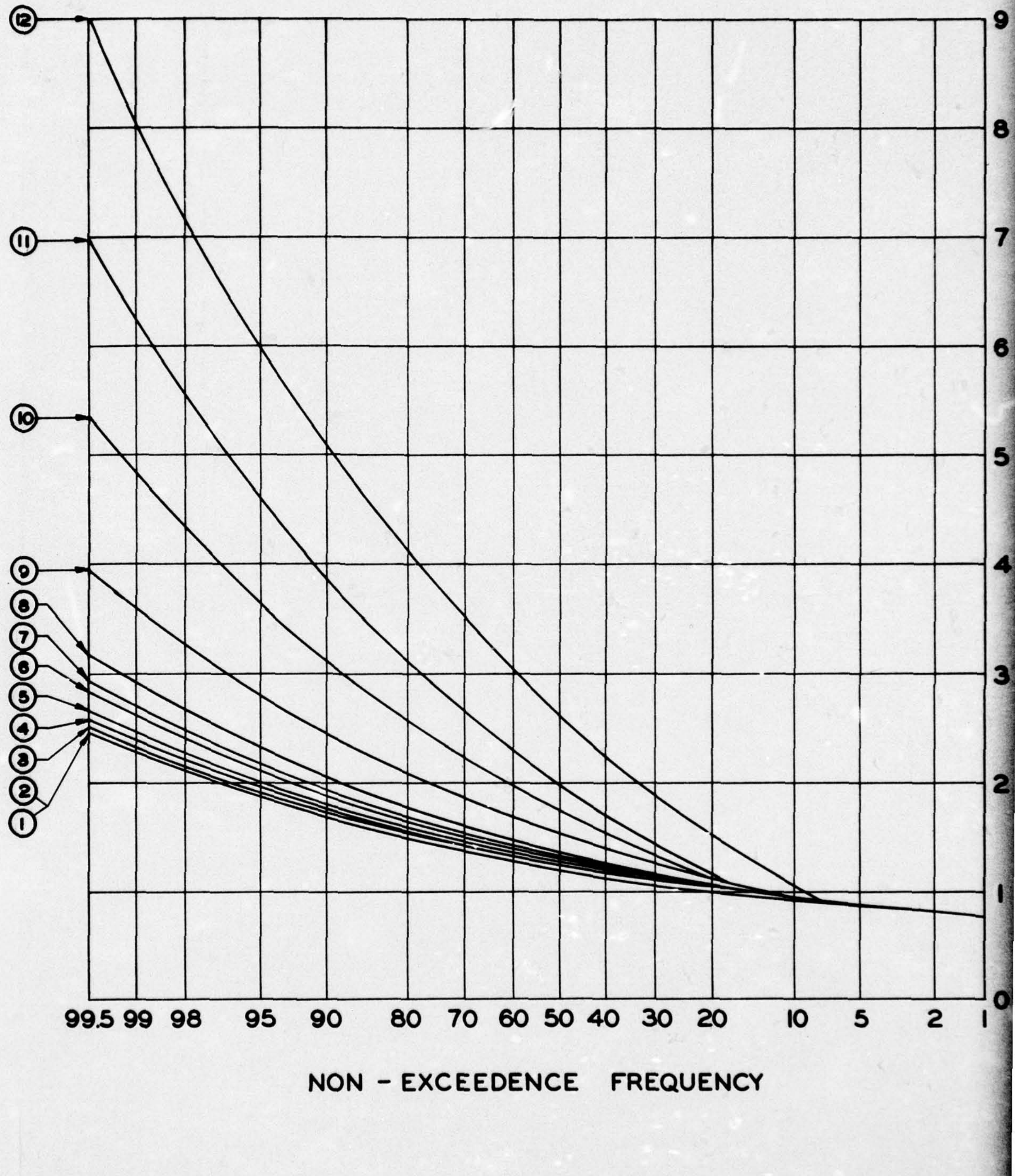


MERAMEC RIVER BASIN, MISSOURI

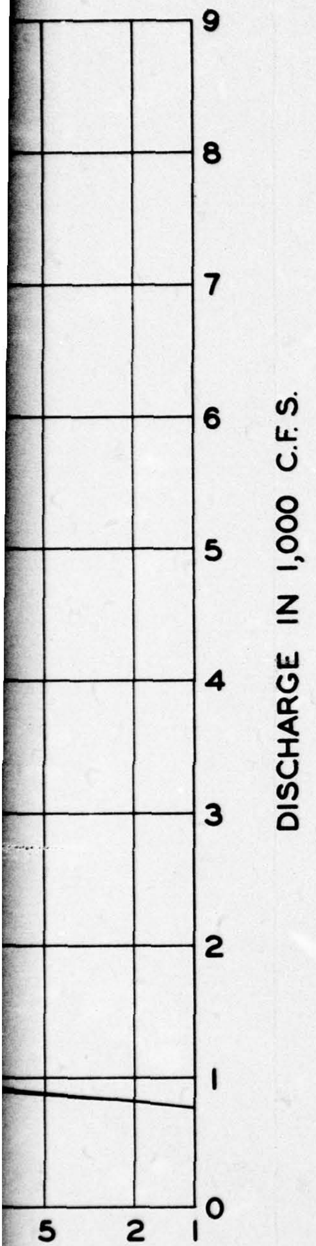
STEELVILLE, MO. - NATURAL AND MODIFIED DISCHARGE FREQUENCY

SCALE AS SHOWN

U. S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

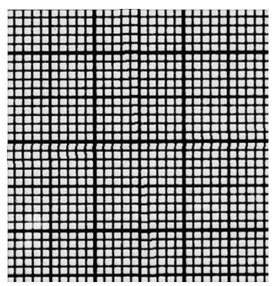

12
11
10
9
8
7
6
5
4
3
2
1
9
8
7
6
5
4
3
2
1
0
99.5 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1
NON - EXCEEDENCE FREQUENCY

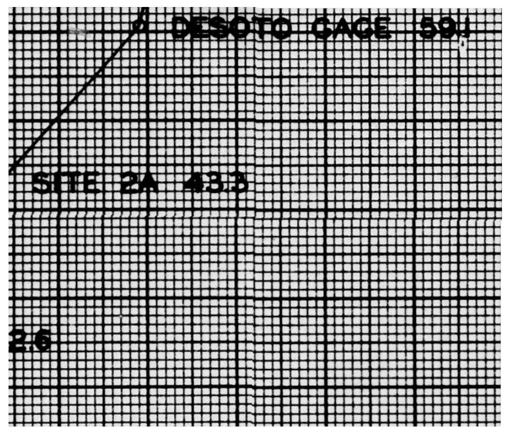
2

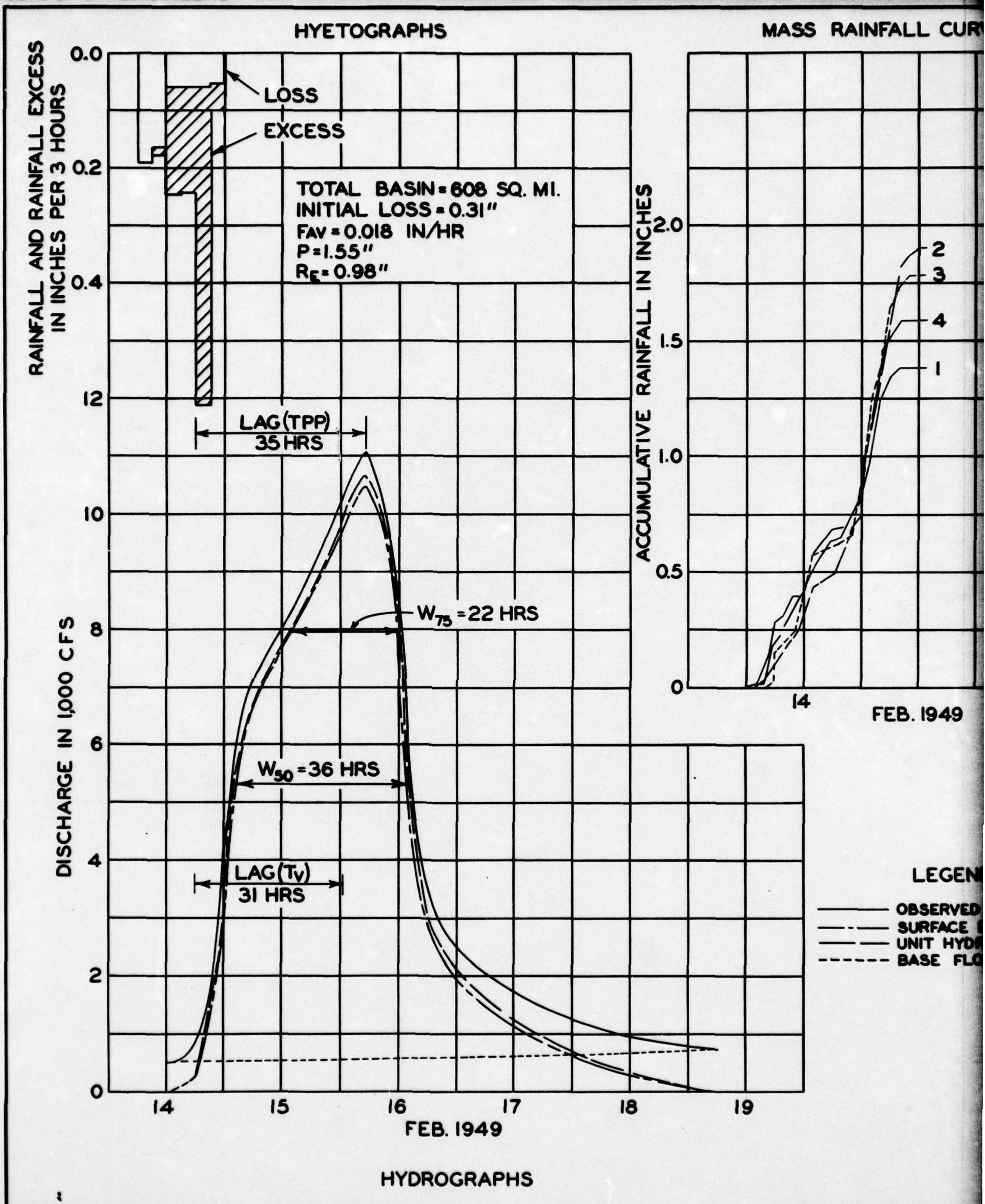


(1) 1 - DAY INSTANTANEOUS
(2) 24 - HOUR MEAN
(3) 3 - DAY MEAN
(4) 5 - DAY MEAN
(5) 10 - DAY MEAN
(6) 15 - DAY MEAN
(7) 20 - DAY MEAN
(8) 30 - DAY MEAN
(9) 60 - DAY MEAN
(10) 90 - DAY MEAN
(11) 120 - DAY MEAN
(12) 180 - DAY MEAN

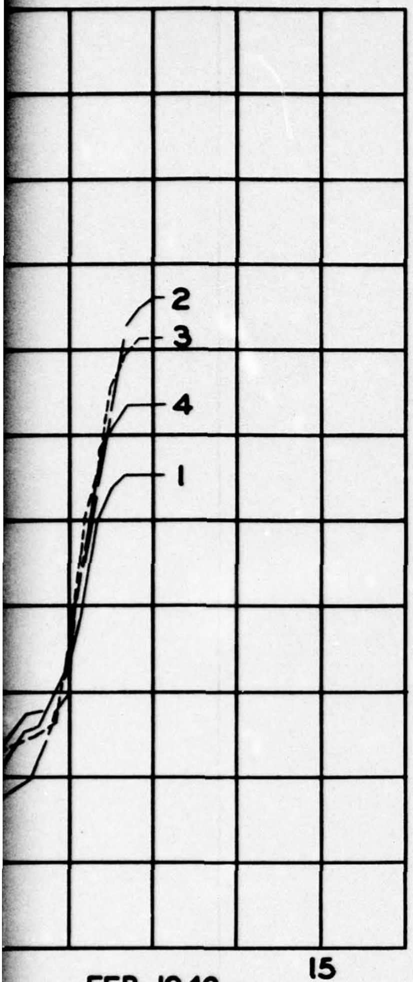
MERAMEC RIVER BASIN, MISSOURI
STEELVILLE, MO. - LOWEST ANNUAL
MEAN FLOW FREQUENCY
SCALE AS SHOWN
U. S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI



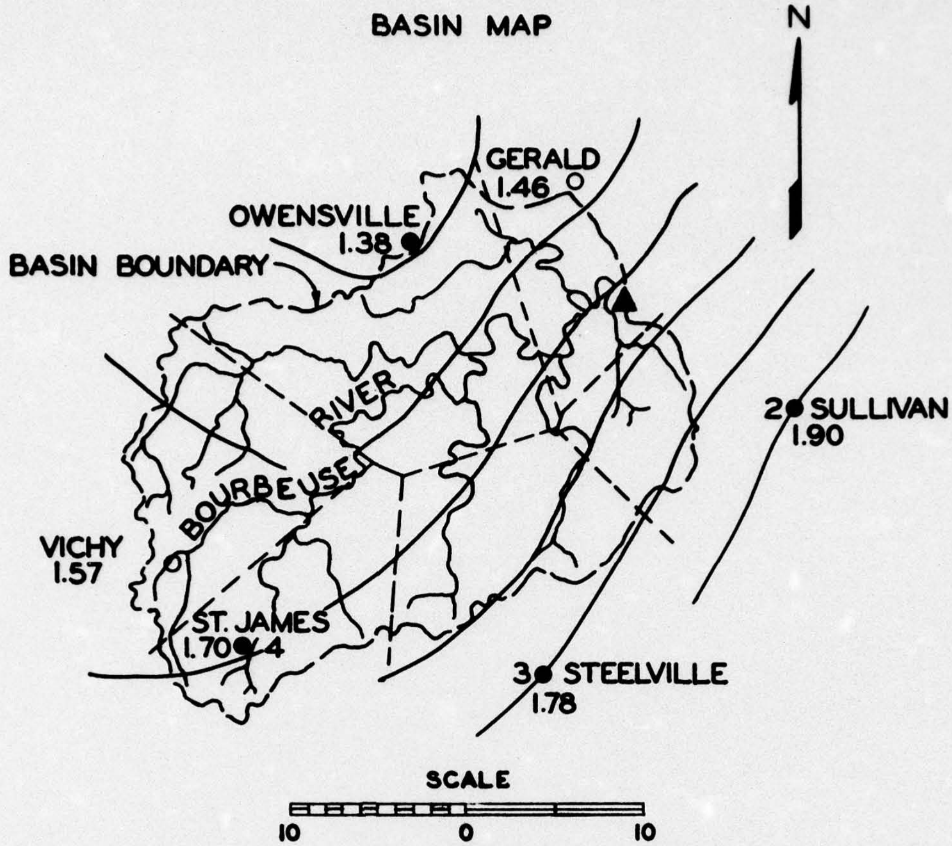

DESOTO GAGE 59J
SITE 2A 43.3
2.6


HYETOGRAPHS
MASS RAINFALL CUR
RAINFALL AND RAINFALL EXCESS IN INCHES PER 3 HOURS
0.0
0.2
0.4
LOSS
EXCESS
TOTAL BASIN = 608 SQ. MI.
INITIAL LOSS = 0.31"
FAV = 0.018 IN/HR
P = 1.55"
RE = 0.98"
ACCUMULATIVE RAINFALL IN INCHES
2.0
1.5
1.0
0.5
0
2
3
4
1
14
FEB. 1949
LAG (TPP) 35 HRS
W75 = 22 HRS
W50 = 36 HRS
LAG (TV) 31 HRS
DISCHARGE IN 1,000 CFS
12
10
8
6
4
2
0
14
15
16
17
18
19
FEB. 1949
HYDROGRAPHS
LEGEN
OBSERVED
SURFACE
UNIT HYD
BASE FLO

RAINFALL CURVES



BASIN MAP



LEGEND

	REC	NON REC
PRECIPITATION GAGES	●	○
STREAM GAGES	▲	Δ
ISOHYETS	———————	
THIESSEN POLYGON	- - - - - - - -	
BASIN BOUNDARY	——— ——— ———	

LEGEND

——— OBSERVED HYDROGRAPH
—·— SURFACE RUNOFF
— — UNIT HYDROGRAPH
------ BASE FLOW

MERAMEC RIVER BASIN, MISSOURI
BOURBEUSE RIVER-UNIT
HYDROGRAPH DETERMINATION
SCALE AS SHOWN
U. S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

DEPARTMENT OF THE ARMY

CORPS OF ENGINEERS

UNIT HYDROGRAPH BASIC DATA SHEET

(SHEET 2 OF 2)

(7) STREAM AND STATION Bourbeuse near Spring Bluff LAT. 38°18'40" LONG. 91°16'45"

(8) DATE OF STORM 14 February 1949 (9) OFFICE St. Louis District

(10) DRAINAGE AREA 608 SQ.MI. (11) L 69.7 MI. (12) L_{ca} 35.0 MI. (13) $(LL_{ca})^{0.3}$ 10.38

(14) AVERAGE RAINFALL 1.55 IN. (15) t_R 15 HRS. (16) DIRECT RUNOFF 0.98 IN.

(17) Q_{pR} 10,650 CFS. (18) q_{pR} 17.52 CFS/SQ.MI. (19) Q_D 11,450 CFS. (20) t_{pR} 35 HRS.

(21) t_p 30* HRS. (22) t_v 31 HRS. (23) C_{tR} 3.37 (24) $C_p{}^{640}$ 613 W_{50} 36 HRS. W_{75} 22 HRS.

TIME Feb. 1949 (25)	OBSERVED DISCHARGE (~~1000~~ CFS) (26)	ESTIMATED BASE FLOW (~~1000~~ CFS) (27)	DIRECT RUNOFF (~~1000~~ CFS) (28)	OBSERVED 15 HR UNIT HYDROGRAPH (~~1000~~ CFS) (29)	ADJUSTED 6 HR UNIT HYDROGRAPH (~~1000~~ CFS) (30)	REPRODUCED STORM HYDROGRAPH (~~1000~~ CFS) (31)	(32)	(33)
14-12-N	550	550	0	0	0			
6-P	840	550	290	290	500			
12-M	3,910	550	3,360	3,410	4,900			
15-6-A	7,150	550	6,600	6,700	7,300			
12-N	8,160	550	7,610	7,730	8,700			
6-P	9,040	560	8,480	8,620	10,600			
9-P	-	-	-	-	11,450			
12-M	10,250	570	9,680	9,840	11,100			
16-5-A	11,060	580	10,480	10,650	-			
6-A	10,970	580	10,390	10,560	9,200			
12-N	8,380	590	7,790	7,920	5,000			
6-P	3,550	600	2,950	3,000	2,300			
12-M	2,540	600	1,940	1,970	1,700			
17-6-A	2,240	610	1,630	1,660	1,300			
12-N	1,740	620	1,120	1,140	950			
6-P	1,430	630	800	810	700			
12-M	1,240	650	590	600	500			
18-6-A	1,120	670	450	460	300			
12-N	1,030	690	340	350	200			
6-P	930	710	220	220	100			
12-M	850	730	120	120	50			
19-6-A	760	760	0	0	0			
Totals cfs/6 hrs	76,690	12,325	64,360	65,400	65,400			

*Due to time shift of rainfall excess.

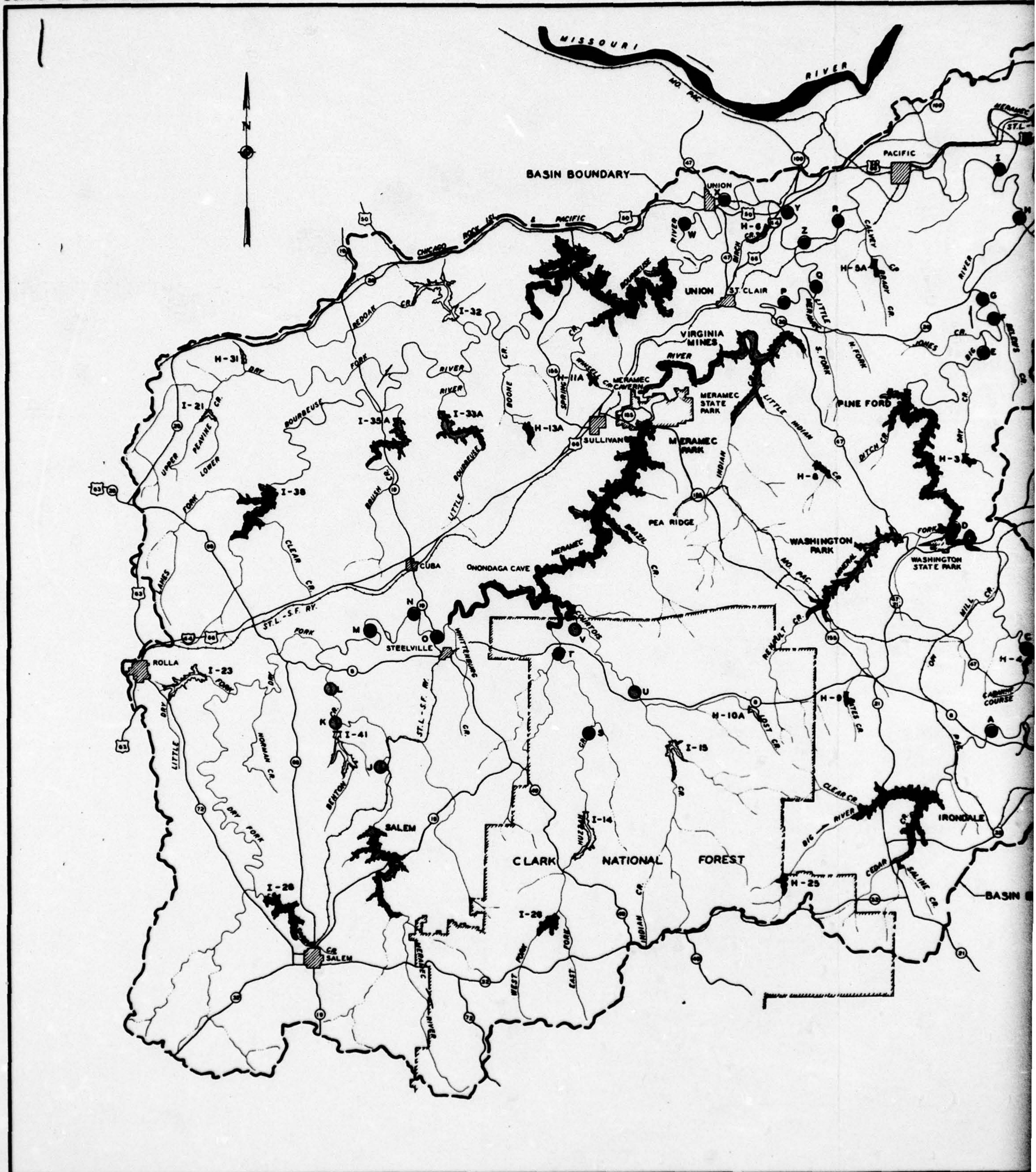
DATE

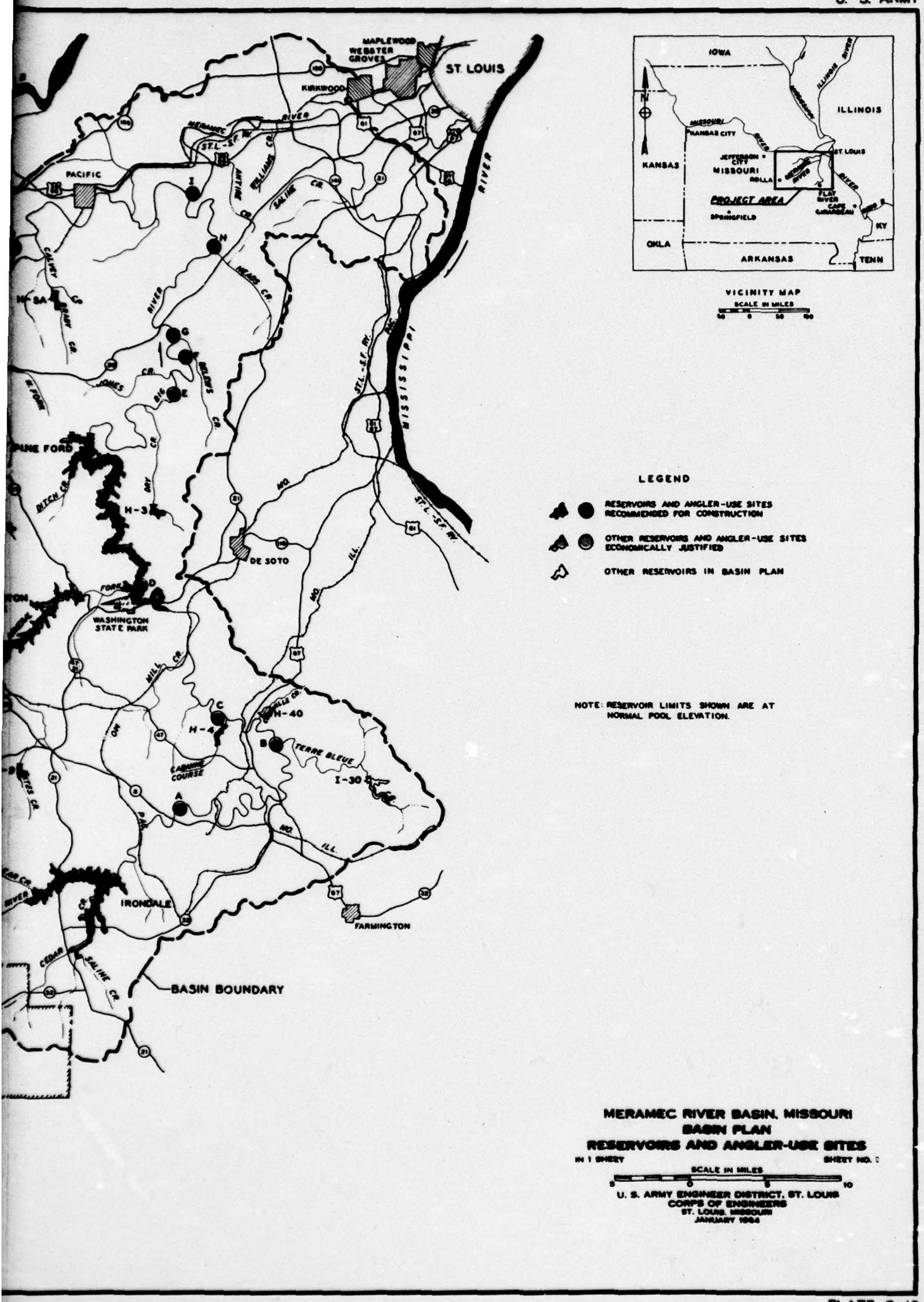
COMPUTED BY

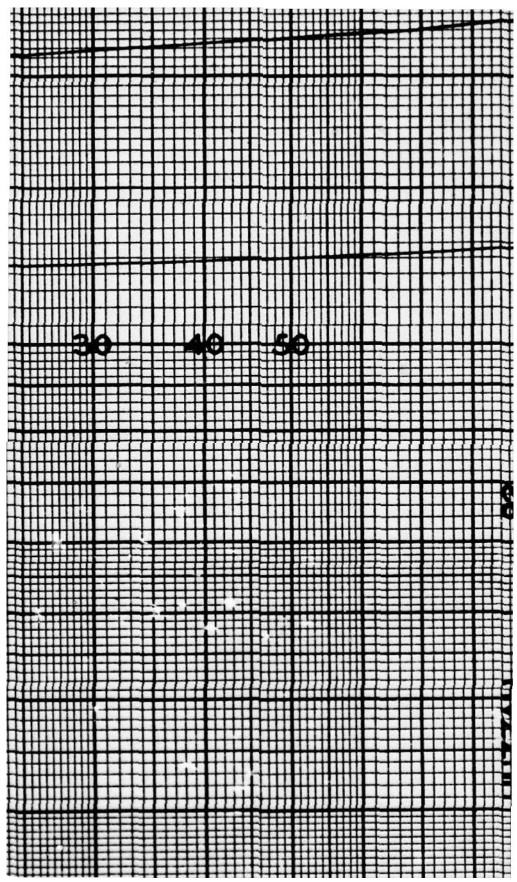
MERAMEC RIVER BASIN, MISSOURI
BOURBEUSE RIVER-UNIT
HYDROGRAPH DETERMINATION
BASIC DATA SHEET
SCALE AS SHOWN
U. S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

ENG FORM 1 NOV 49 1823

CORPS OF ENGINEERS



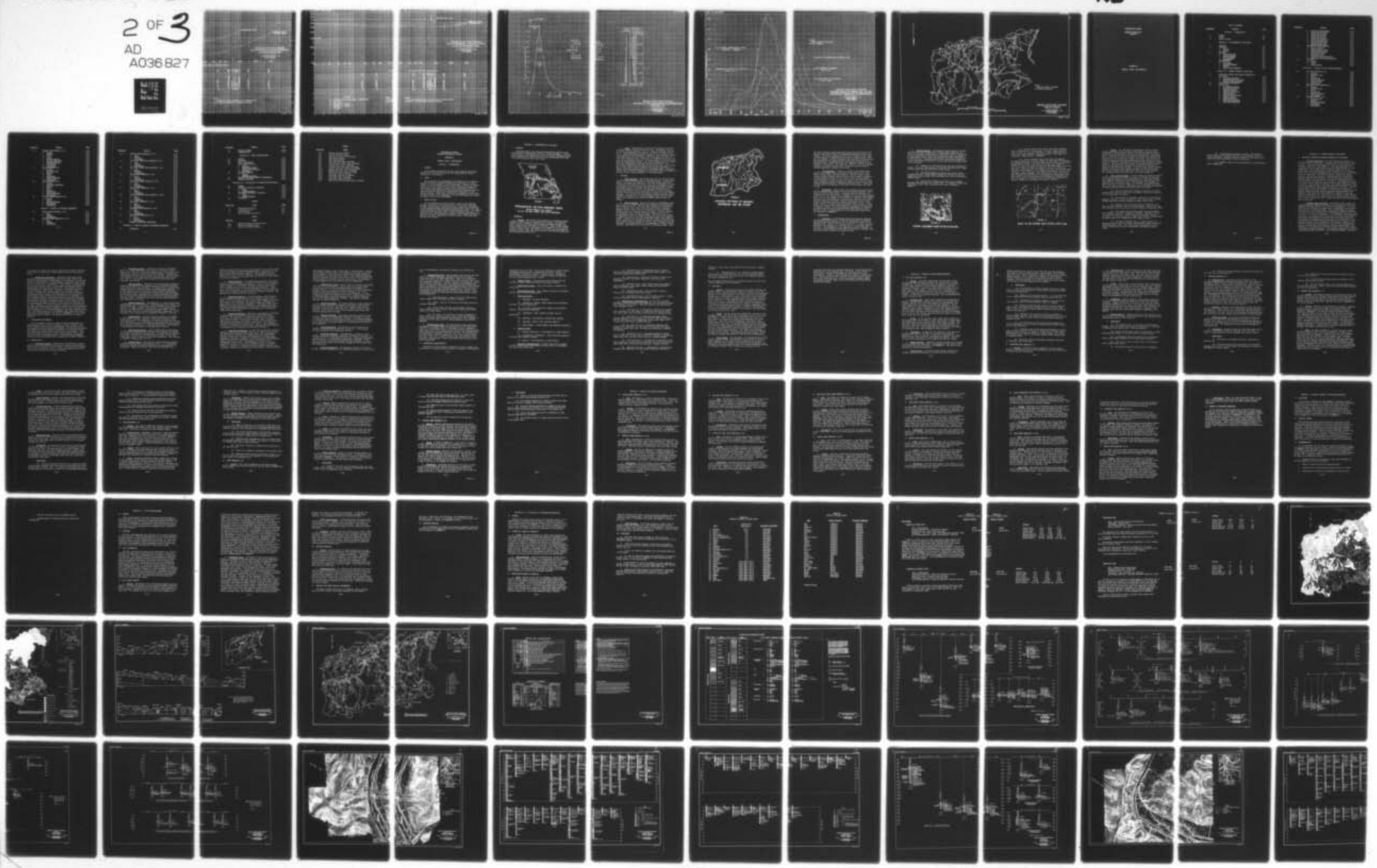

MAPLEWOOD
WEBSTER GROVES
ST. LOUIS
KIRKWOOD
PACIFIC
MERAMEC RIVER
MISSISSIPPI RIVER
DE SOTO
WASHINGTON STATE PARK
IRONDALE
FARMINGTON
TERRE BLEUE
BASIN BOUNDARY
VICINITY MAP
SCALE IN MILES
IOWA
ILLINOIS
KANSAS
MISSOURI
OKLA
ARKANSAS
KY
TENN
KANSAS CITY
JEFFERSON CITY
ROLLA
SPRINGFIELD
PROJECT AREA
FLAT RIVER
LEGEND
RESERVOIRS AND ANGLER-USE SITES RECOMMENDED FOR CONSTRUCTION
OTHER RESERVOIRS AND ANGLER-USE SITES ECONOMICALLY JUSTIFIED
OTHER RESERVOIRS IN BASIN PLAN
NOTE: RESERVOIR LIMITS SHOWN ARE AT NORMAL POOL ELEVATION.
MERAMEC RIVER BASIN, MISSOURI
BASIN PLAN
RESERVOIRS AND ANGLER-USE SITES
IN 1 SHEET
SCALE IN MILES
U. S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI
JANUARY 1964

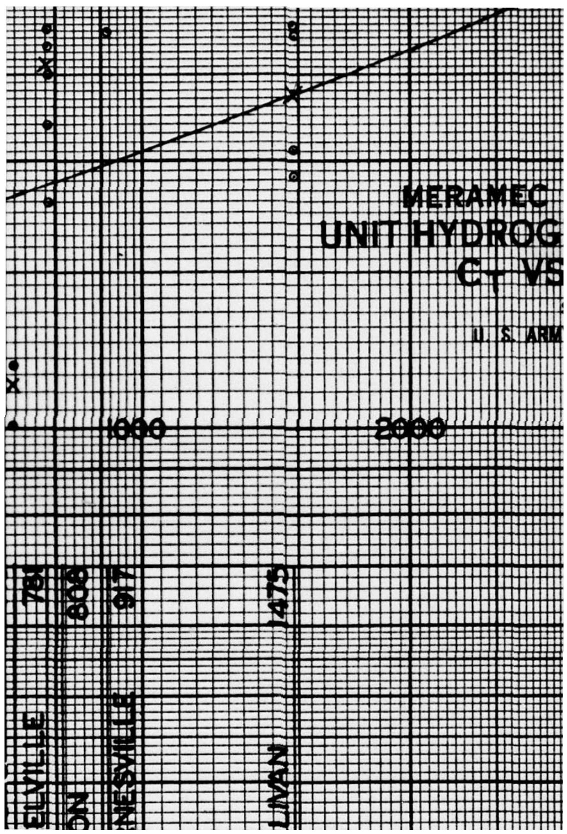

30
40
50

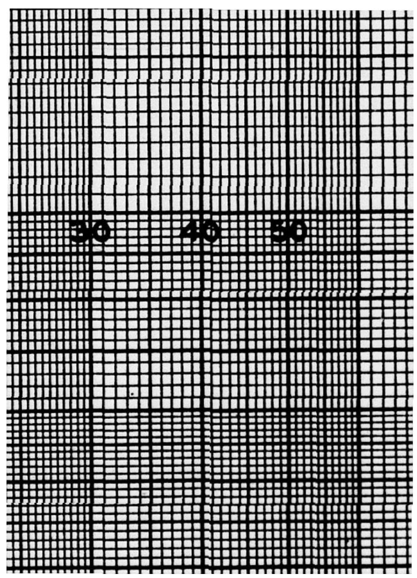
AD-A036 827 ARMY ENGINEER DISTRICT ST LOUIS MO F/G 8/6
MERAMEC RIVER, MISSOURI COMPREHENSIVE BASIN STUDY. VOLUME IV. A--ETC(U)
JAN 64

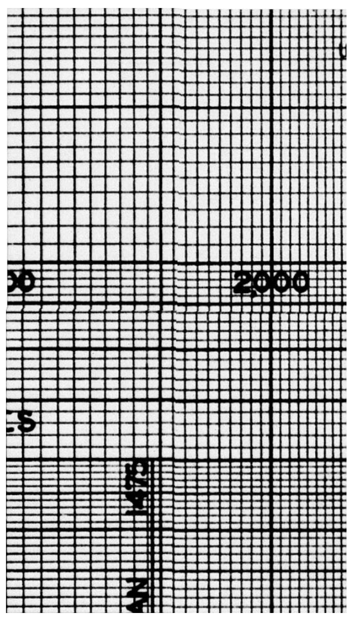
UNCLASSIFIED NL

2 OF 3
AD
A036827

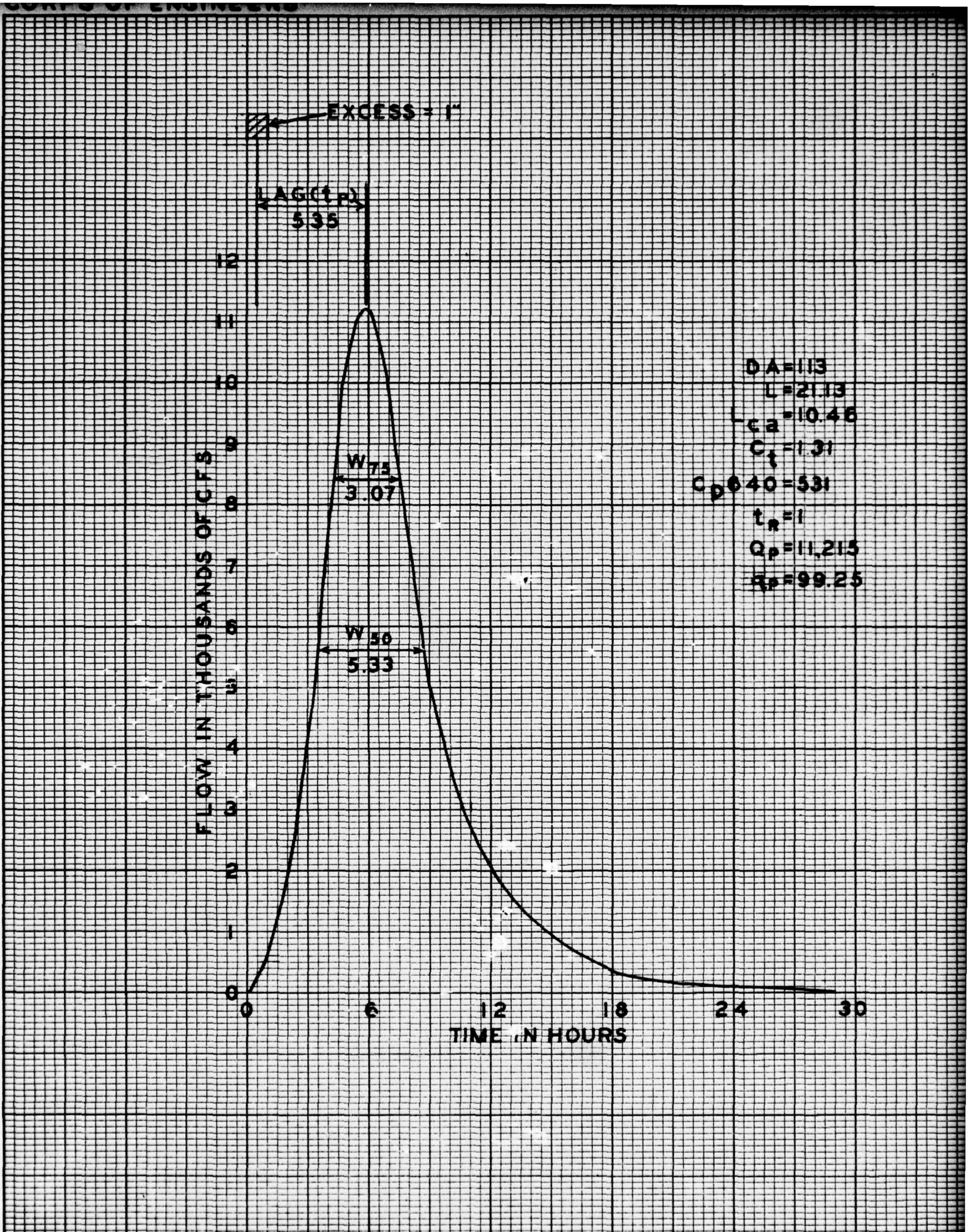



MERAMEC
UNIT HYDROG
CT VS
U. S. ARM
1000
2000
781
808
917
1475
ELVILLE
ON
NESVILLE
LMAN


30
40
50


2000
1475

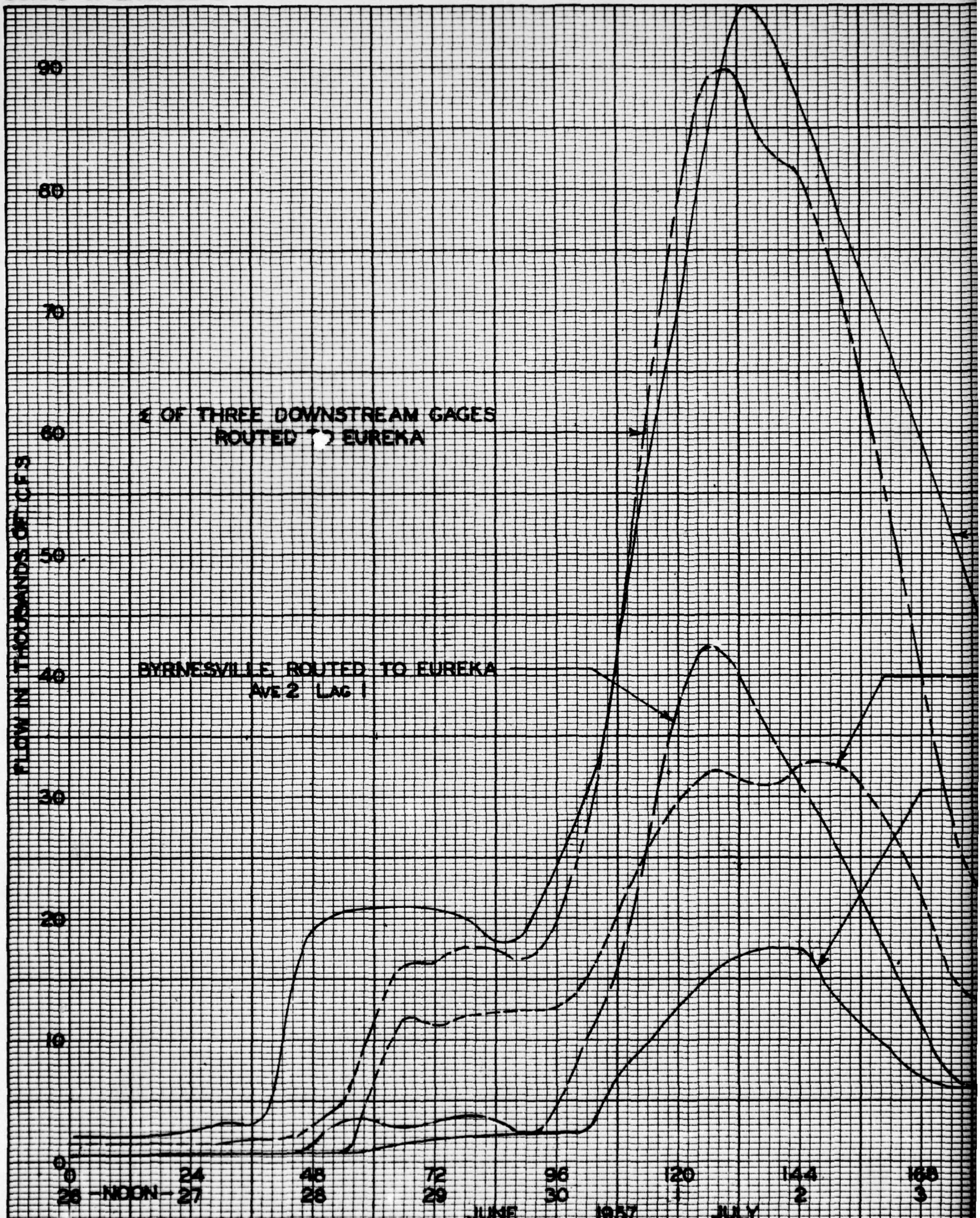
1

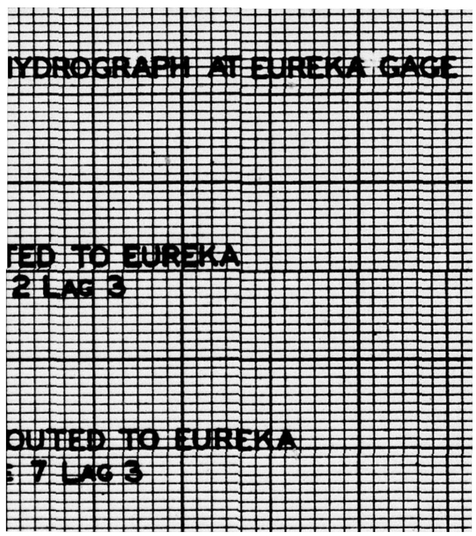

EXCESS = 1"
LAG (tp)
5.35
W75
3.07
W50
5.33
DA = 113
L = 21.13
Lca = 10.46
Ct = 1.31
Cp640 = 531
tR = 1
Qp = 11,215
qp = 99.25
FLOW IN THOUSANDS OF CFS
TIME IN HOURS
0
1
2
3
4
5
6
7
8
9
10
11
12
0
6
12
18
24
30

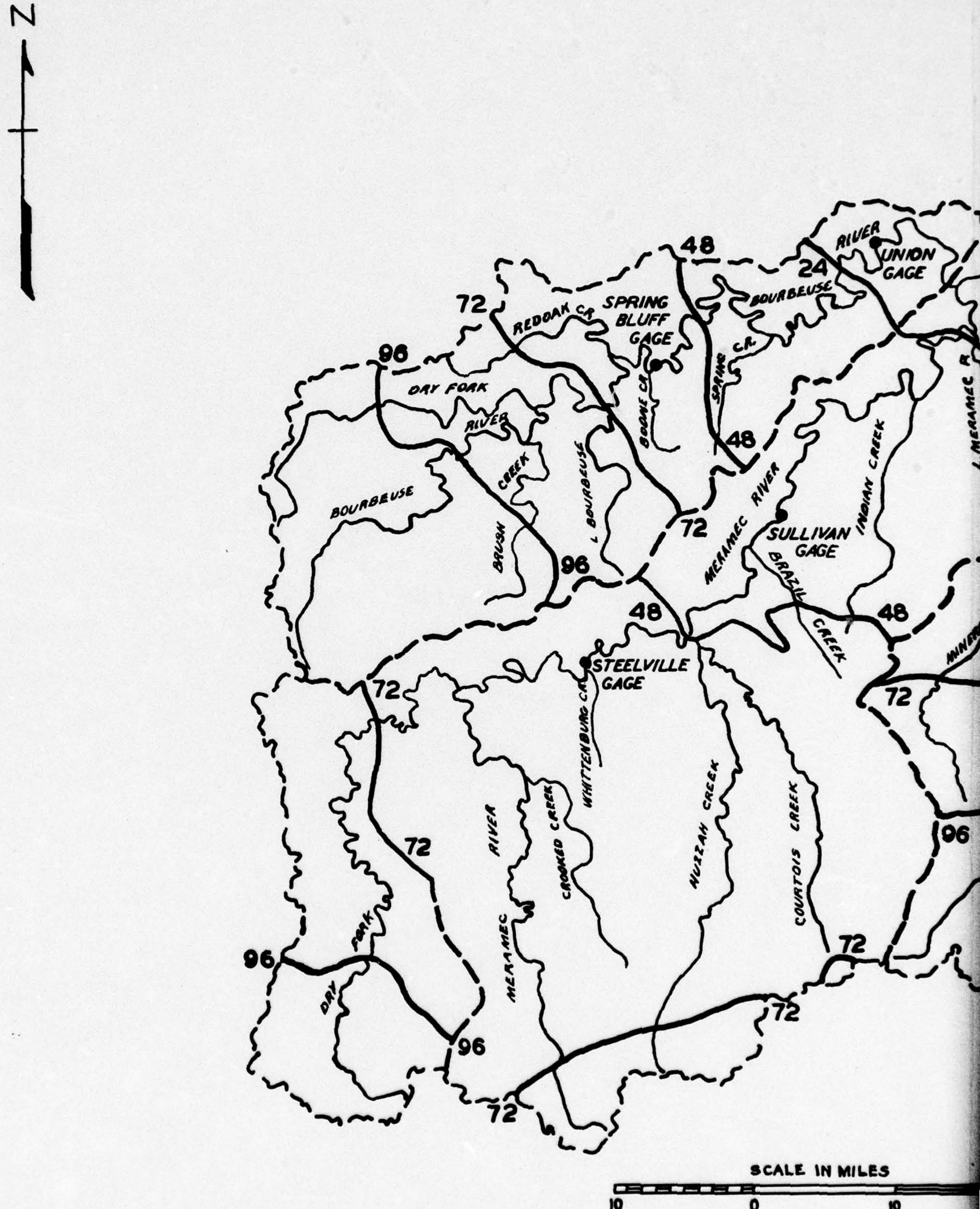
A=113
L=21.13
a=10.46
t=1.31
0=531
R=1
P=11,215
=99.25

TIME HOURS	ORDINATES C F S	
	$t_R=1$	$t_R=6$
0	0	0
1	800	
2	2,000	
3	4,200	
4	7,200	
5	10,400	
6	11,200	5,935
7	9,700	
8	7,450	
9	5,150	
10	3,710	
11	2,700	
12	2,060	5,128
13	1,560	
14	1,220	
15	940	
16	710	
17	530	
18	380	890
19	260	
20	210	
21	160	
22	140	
23	120	
24	100	168
25	80	
26	60	
27	40	
28	20	
29	0	
30	0	33
TOTAL	72,920	12,154

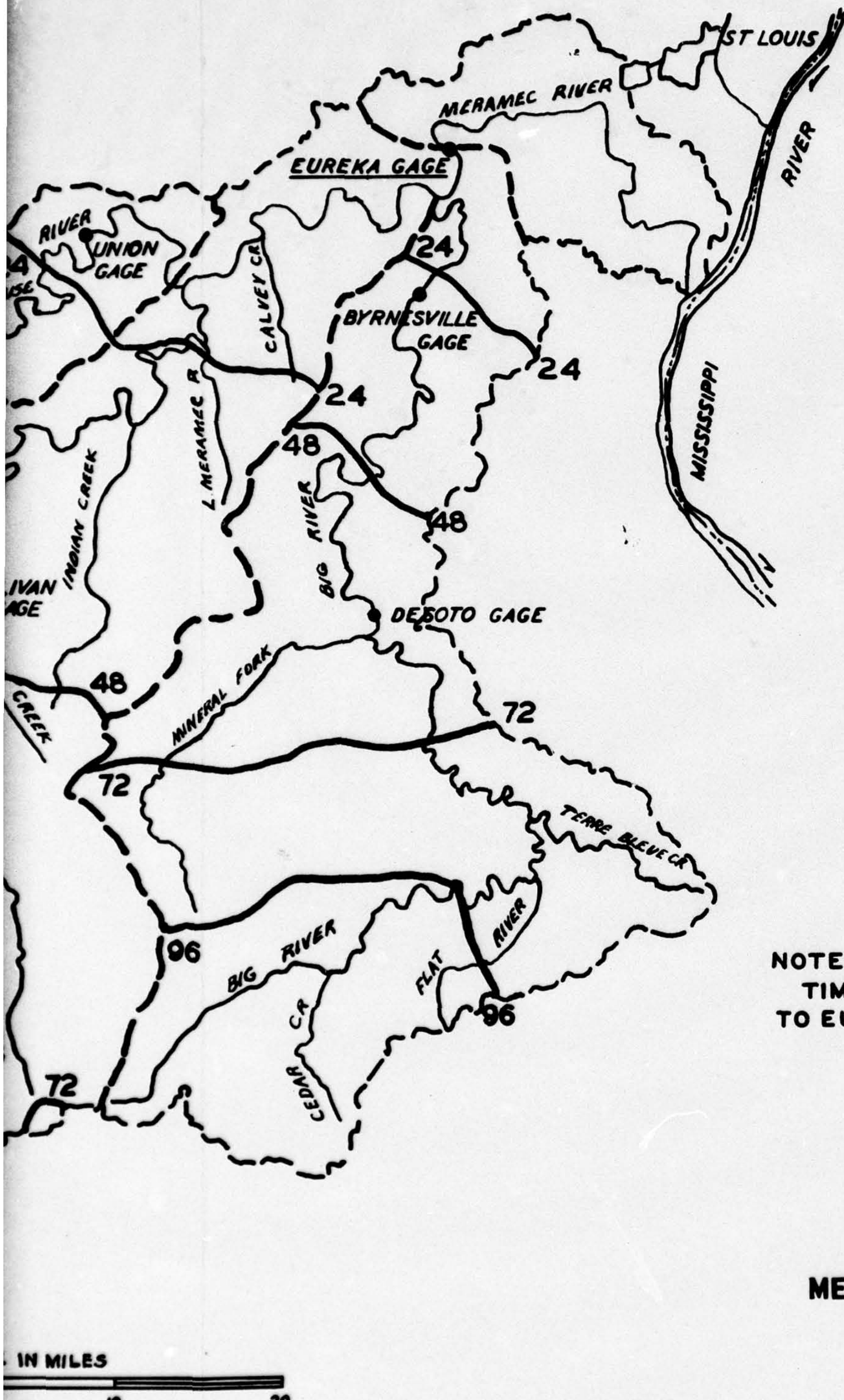
CORPS OF ENGINEERS




YDROGRAPH AT EUREKA GAGE
TED TO EUREKA
2 LAG 3
OUTED TO EUREKA
7 LAG 3


N
48
24
RIVER
UNION GAGE
72
REDOAK CR.
SPRING BLUFF GAGE
BOURBEUSE
SPRING CR.
96
DRY FORK
RIVER
BOONE CR.
L. MERAMEC R.
48
INDIAN CREEK
CREEK
BOURBEUSE
L. BOURBEUSE
72
MERAMEC RIVER
SULLIVAN GAGE
BRUSH
96
BRAZIL CREEK
48
48
STEELVILLE GAGE
72
72
WHITTENBURG CR.
RIVER
CROOKED CREEK
HUZZAH CREEK
COURTOIS CREEK
96
72
MERAMEC
DRY FORK
96
72
72
96
72
SCALE IN MILES
10
0
10

2



NOTE:-
TIME OF TRAVEL IN HOURS
TO EUREKA, MISSOURI

MERAMEC RIVER BASIN, MISSOURI

TIME OF TRAVEL

SCALE AS SHOWN

U. S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

COMPREHENSIVE REPORT

MERAMEC RIVER BASIN,
MISSOURI

APPENDIX D

GEOLOGY, SOILS, AND MATERIALS

TABLE OF CONTENTS

FIGURES

TABLES

PLATES

COMPREHENSIVE REPORT
MERAMEC RIVER BASIN, MISSOURI

APPENDIX D

GEOLOGY, SOILS, AND MATERIALS

SECTION I - INTRODUCTION

1. PURPOSE

This appendix presents all geologic data obtained from investigations and research that influence the engineering and economic feasibility of the project.

2. SCOPE

The presentation is comprehensive and basinwide in its approach in order to obtain a degree of flexibility in the event of future changes in site selection or plan of improvement. However, sufficient detail on the basic features of the plan is included to support the conclusions of the report. Several of the many possible reservoir sites selected for preliminary investigation were eliminated from further consideration because of obviously poor foundations or other geologic reasons. Those sites eliminated for geologic or other reasons are not discussed in this appendix. All sites investigated are shown on PLATES 2 and 3 of the MAIN REPORT.

3. SOURCE OF DATA

The investigations performed include a study of all available geologic literature, field reconnaissance, core borings, hand auger borings, and preliminary laboratory testing. Most of the information on the basinwide geology was obtained from published reports and unpublished manuscripts of the Missouri State Geological Survey. Dr. Thomas R. Beveridge, State Geologist, and his staff of geologic specialists contributed much to the information contained in this appendix through the mediums of personal communication, special studies, and helpful suggestions and critique.

SECTION II - PHYSIOGRAPHY OF THE BASIN

4. LOCATION

The Meramec Basin lies within the Salem Plateau section of the Ozark Plateaus' physiographic province as shown in FIGURE 1. The Big River drains the northern portion of the St. Francois Mountain section, and the Meramec River empties into the broad Mississippi River plain a few miles below the city of St. Louis.

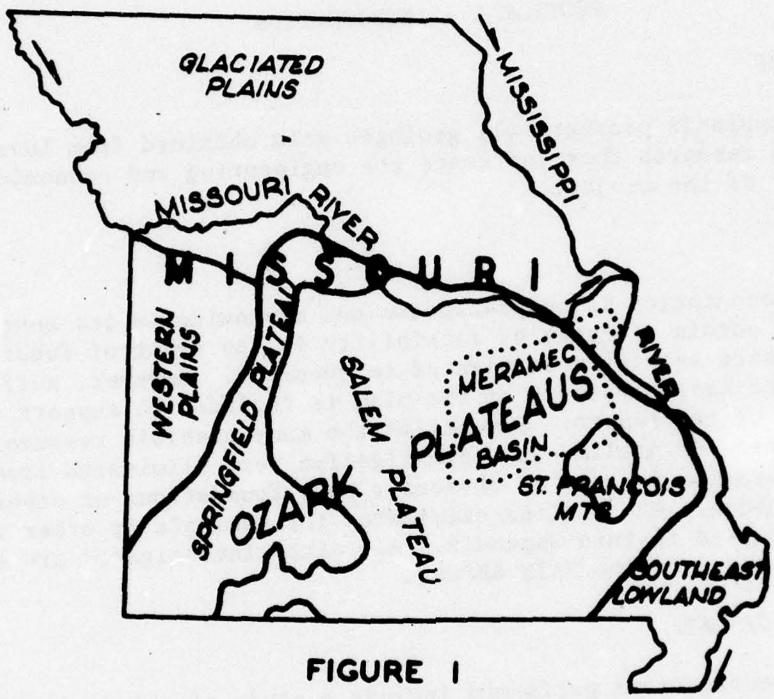


FIGURE 1

PHYSIOGRAPHIC SETTING—MERAMEC BASIN

SOURCE: BECKMAN AND HINCHEY

VOL. XXIX, MO. GEOL. SURVEY AND WATER RESOURCES

5. TOPOGRAPHY

a. <u>General</u>. The basin is characterized by a relatively rugged topography, particularly so adjacent to the streams. The divides, however, consist of gently rolling uplands containing sizeable flat areas locally called "flatwoods" or "prairies". Many of these uplands contain sinkholes and are considered to be remnants of an old erosion surface of small relief. The valleys are for the most part steep and relatively narrow, with some nearly vertical rock bluffs extending over 200 feet above the valley flat.

b. Relief. The average elevation of the uplands in the basin is between 900 to 1,000 feet above sea level. The highest point is the crest of Johnson Mountain, given as slightly exceeding 1,700 feet m.s.l. Johnson Mountain is located in the extreme southern portion of the basin near the headwaters of Big River. The streambed, located less than a mile from the mountain, has an elevation some 700 feet lower than Johnson's crest. Local relief is commonly as great as 400 feet and very commonly 200 feet. The lowest point in the basin occurs where the Meramec River empties into the Mississippi River, the flood plain here maintaining an average elevation of 400 feet. The St. Francois Mountain section contains the highest hills in the basin. Many of these have crests exceeding 1,400 feet and bare knobs of igneous rock which protrude above the surrounding upland. This area and the deeply dissected headwaters of the Huzzah Creek (see PLATE D-1) contain the most rugged topography of the Meramec Basin.

6. DRAINAGE

a. Characteristics. The Meramec River and its two main tributaries exhibit contrasting forms of drainage patterns. The Bourbeuse pattern is symmetrically dendritic with evenly spaced tributaries entering from both south and north. This type of drainage is in part a reflection of relatively soft rock underlying the Bourbeuse Basin. The Meramec pattern is asymmetrical with the preponderance of tributaries entering from the south. The abundance of north flowing streams here appears to be a consequence of the initial slope away from the axis of the uplifted area south and west of the St. Francois Mountains. The Big River in the headwaters exhibits modified radial drainage, influenced by the resistant igneous knobs and local high areas. These patterns are readily discernible and are shown in FIGURE 2.

b. Natural springs. Each of the rivers in the Meramec system has at least one tributary maintaining a minimum flow exceeding one million gallons per day. The only such tributary of the Bourbeuse River is Spring Creek, which enters the river north of Stanton in Franklin County. This creek is sustained by the flow from Kratz Spring, one of the larger springs in the basin. The main tributary of the Meramec River, ranked according to minimum flow, is the Huzzah-Courtois Creek in Crawford County. The flow of this stream is augmented by water from Westover Spring and many lesser magnitude springs. Big River has two main tributaries, Mineral Fork and Mill Creek. Racing and Cold Springs are the main feeders of Mineral Fork, while Hopewell Spring sustains Mill Creek. The discharge of springs, therefore, contributes greatly to the maintenance of stream flow in the basin, particularly so in the times of prolonged drought. There

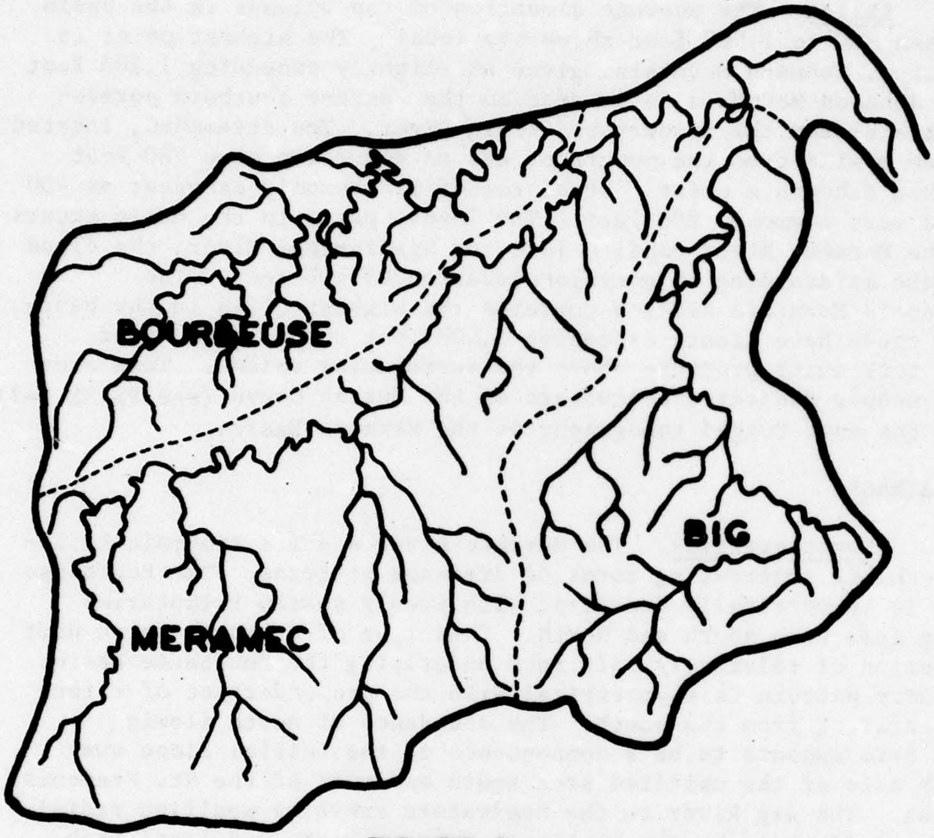


FIGURE 2

DRAINAGE PATTERNS OF MERAMEC BOURBEUSE AND BIG RIVERS

are some 30 springs in the basin whose flows have been measured, and many more smaller or difficultly measureable springs are known to be present. The largest spring, located 6 miles southeast of St. James in Phelps County, is approximately the seventh largest spring in the State of Missouri, and has an average daily flow of 96 million gallons. The concentration of larger springs is along the Meramec River in Crawford County. Comparatively few large springs discharge into the Bourbeuse or Big Rivers. See PLATE D-1. TABLE D-1 lists the measured springs of the basin, showing their average flow and the known or inferred geological formation of the outlet.

c. Dry streambeds. A glance at the map of the Meramec Basin discloses a sizeable number of streams, having names such as "Dry Creek", "Barren Fork", and "Rock Branch". The dry valleys of such streams contain flowing surface water only after torrential downpours or long sustained periods of rain. Most of these valleys contain heavy thicknesses of gravel on the valley floor, and runoff into the valley disappears quickly through this highly pervious gravel to flow along the bedrock surface or through the bedrock itself. Indications are that many of the springs of the basin are fed through such "dry" valleys.

d. Groundwater. That portion of the Meramec Basin above Valley Park is abundant in groundwater from shallow bedrock aquifers. Downstream from Valley Park, depths to suitable aquifers producing any sizeable yield are much greater. Throughout most of the basin, potable water, low in iron content, can be produced in quantities approximating 20 to 25 G.P.M. from depths of 150 to 250 feet. Because of the highly permeable nature of the cherty, unconsolidated mantle and the prevalence of solutionized dolomitic bedrock encountered in most of the stream divides, the slope of the groundwater surface is low. In many places, the water surface beneath the divide is at or below the level of adjacent streams. Salty and sulphurous groundwater is encountered at depths below 500 feet in the lower basin area around St. Louis. Detailed studies of the groundwater use and production capabilities are contained in APPENDIX K.

7. GEOMORPHOLOGY

a. Glaciation. As the Meramec Basin lies below the southernmost advance of the glaciers, it did not experience the scouring and subsequent mantling with glacial drift as did the area north of the Missouri River. Deposits of loess are restricted to a small area near the mouth of the Meramec and a sizeable area on the northern edge of the basin. The topography of this unglaciated surface, therefore, is a result of long continued erosion and the dissection by streams, somewhat controlled by structure and repeated uplift.

b. <u>Erosional aspects</u>. Following the final retreat of the seas from this area and the deposition of Pennsylvanian sediments, the basin has undergone several cycles of uplift and erosion. Many of the divides between major tributaries are relatively flat, have summits at approximately equal levels, and represent the oldest erosional surface in the basin. Repeated uplift of this surface and intervening erosion have produced a variety of valley forms within the basin, such as the following.

(1) Remnants of older flood plains have been preserved as benches or terraces consisting of alluvium and occurring on the slopes of wide divides and near the ends of steep ravines.

(2) Entrenched meanders are common on all three rivers draining the basin. A most complex meander is exhibited in the configuration on the Bourbeuse River near Noser Mill north of Sullivan in Franklin County.

(3) Occasionally, meanders have been cut off, leaving abandoned sizeable areas of old flood plain. An example of such a cutoff meander is the "cove" area east of St. Clair, as shown in FIGURE 3.

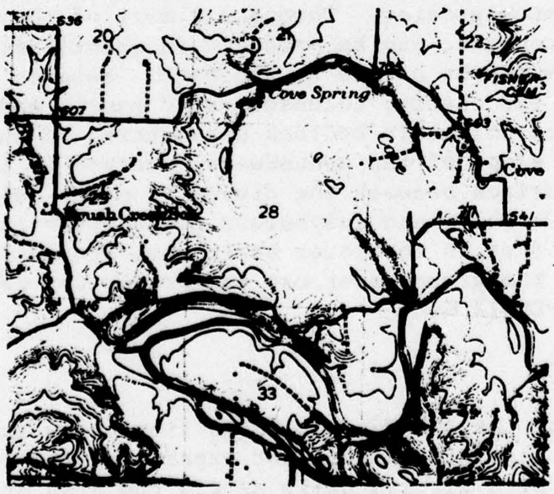


FIGURE 3

CUTOFF MEANDER- EAST OF ST. CLAIR, MO.

(4) On some curves of the rivers, the inner or concave side is approached by a long moderate "slip-off" slope produced by lateral as well as vertical degradation. A good example of such a slope is the right abutment at the Salem damsite. See PLATE E-14, "Salem Dam - Design Details", APPENDIX E.

(5) At the southeast edge of the basin, the igneous St. Francois Mountains protrude as knobs or peaks above the surrounding sedimentary surface. As these knobs were not carved by the present streams but are merely being uncovered by them, the streams are altered in their course away from the more resistant granite or felsite. When such a stream is unable to change its course, it erodes constricted, narrow gorges in the resistant rock, which are locally called "shut-ins". Such "shut-ins" were formerly utilized as sites for small mill dams, taking advantage of the narrow valley width. Several of these features are developed on the headwaters and tributaries of Big River and at least two are known on the headwaters of Huzzah Creek. The site of the H-25 headwater reservoir on the upper Big River, as shown in FIGURE 4, is an example of a typical "shut-in".

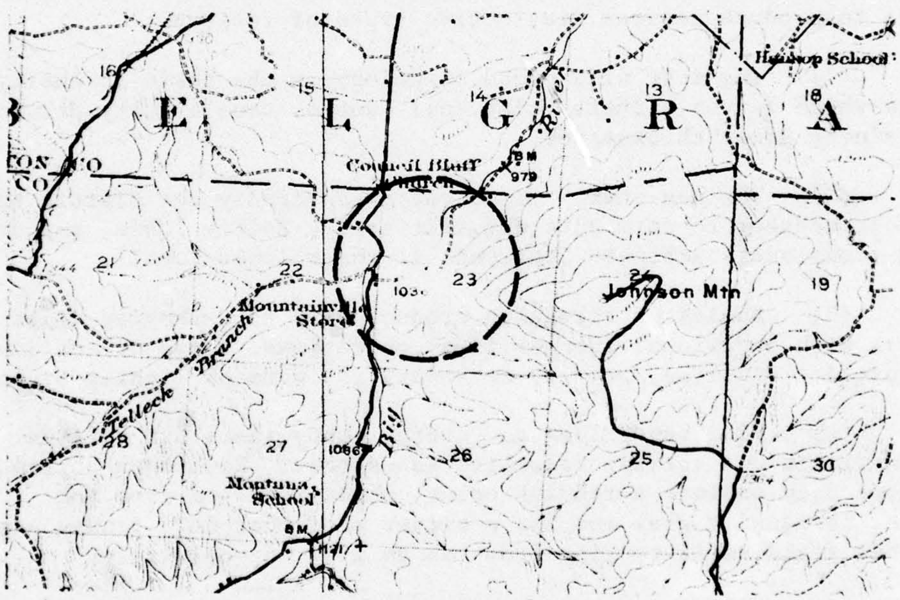


FIGURE 4

SHUT-IN ON UPPER BIG RIVER-SITE H-25

c. Caverns. The combination of unglaciated terrain, preponderance of dolomitic rock, pervious cherty mantle, repeated uplift and movement, and substantial rainfall has been favorable to the formation of caverns and sinks in the Missouri Ozarks and in the Meramec Basin. Three of the caves in the basin are commercially operated and contribute to the recreational economy of the area. The existence of sizeable caverns and their interconnecting solution channels directly affect the problems of leakage from reservoirs and the required remedial measures. In this respect, practically all proposed damsites in this report are confronted with solutionized abutments and deleterious aspects of the subsurface drainage. A list of known, sizeable caverns, showing locations by county and the geological formations in which they occur, is presented in TABLE D-2. This list is not exhaustive for the Meramec Basin, and many others are shown on PLATE D-1.

d. Soil - rock relations. As the residuum overlying the bedrock surface of the basin is primarily a result of solution, it reflects the lithologic character of the underlying rock. The mantle exhibits every degree of removal of soluble material, and sharp contacts with unaltered rock are extremely rare. The thickness of this mantle is known from drill records to range up to 150 feet and probably exceeds this at selected localities. The parent rock in the basin has weathered in place to produce several distinctive types of residuum:

(1) The most widespread lithology in the basin is cherty dolomite which leaves a cherty clay soil mantle, usually very pervious, and attaining great thicknesses.

(2) The non-cherty limestones, especially the Plattin and Kimmswick, weather to form clay and silt soils, fairly loose, and containing occasional carbonate fragments in their lower levels.

(3) Shales of the basin produce gray to dark-gray silts and clays with occasional iron or lime concretions. Some of the lower shales produce ash-like, powdery to sheety residuum of light-gray color.

(4) Fine sandy loam and cherty sandy loams are residual from sandstones and cherty, dolomitic sandstones. Roubidoux derived soils generally exhibit a reddish color, while residuum from the St. Peter is usually gray and has a higher sand content. Pennsylvanian sandstones yield soils ranging from red to gray to yellow.

(5) The Potosi formation and, to a lesser extent, the Eminence produce a deep-red, sticky, clay residuum, almost universally containing quartz druse. This type of clay is distinctive to the Potosi formation and occurs in considerable thicknesses on gentle slopes.

(6) A predominantly yellowish, cherty, clay residuum is derived from the argillaceous dolomites of the Jefferson City and related formations. Dependent upon the character of the parent rock, these soils vary considerably in their sand content.

(7) PLATE D-1 shows the area distribution of lithologically similar formations.

SECTION III - GENERAL GEOLOGY OF THE BASIN

8. GEOLOGICAL ASPECTS AND MINERAL RESOURCES OF SUB-BASINS

a. Big River Sub-basin. The oldest Paleozoic sediments in Missouri, as well as the areas of igneous rock on the northern flanks of the St. Francois Mountains, are drained by the Big River and its headwater tributaries. See PLATE D-1. The underlying rocks dip slightly to the north and northeast and have been disturbed by small displacement fault systems which are partly responsible for the preservation of mineral deposits in the watershed. In St. Francois County, the area surrounding Bonne Terre and Flat River, long referred to as the "Lead Belt", has been the Nation's leading lead mining district, most of the production being obtained from disseminated galena in the Bonneterre dolomite. Through increased exploration and development, new large deposits of lead are being opened to the west and north, expanding the old "Lead Belt". Washington County and, to a lesser extent, Jefferson County contain large commercial deposits of barite in the residuum of the Potosi and Eminence formations. This area is the principal barite producing district in Missouri. Dolomites of the Jefferson City and Bonneterre formations are quarried for crushed stone, and, near the mouth of the Big River, limestones of the Plattin formation provide concrete aggregate and agricultural lime. Where the river drains the cherty dolomites, deposits of sand and gravel are abundant, while, elsewhere in the sub-basin, these deposits are not as well developed. Many springs issue from the Potosi formation in the sub-basin, but none of these are known to have flows exceeding 2 second-feet.

b. Bourbeuse River Sub-basin. The Bourbeuse River drains an area predominantly underlain by Ordovician argillaceous dolomites and sandstone and Pennsylvanian clays, shales, and sandstones. As these rocks are less resistant to weathering, the topography is more gentle than the rest of the Meramec Basin. The lowlands along the streams are generally quite extensive and are bounded by gradually sloped valley walls, even into the headwaters. The comparative scarcity of chert, especially in the Pennsylvanian rocks, has resulted in the development of thicker, less stony soils, more suited to cropland and pasture. This relatively impervious soil mantle allows for rapid runoff from the uplands, and coupled with the existence of less soluble rock formations, results in the development of few springs or caverns. The principal mineral resource of the area is fire clay, which generally occurs in discontinuous depressions or sinks of varying depth. The deposits are not known to be more than 100 feet thick, and extraction is obtained by open pit methods. Clay currently being mined is distributed along the upper perimeter of the Bourbeuse Sub-basin. Dolomite

is quarried for crushed stone and for agricultural purposes, and sandstone blocks are produced in limited quantities for use as building stone.

c. Meramec River Sub-basin. Cambrian and Ordovician cherty dolomites, having a gentle regional dip to the north, underlie the middle and upper portions of the Meramec River watershed. In the lower portion of the drainage of the main stream, successively higher formations are encountered. See PLATE D-1. The sub-basin is characterized by having steep walled valleys, carrying many caverns and springs; by being mantled with pervious, residual soils; and by having valleys heavily laden with huge deposits of gravel. This gravel, especially in the middle and lower courses, constitutes a valuable mineral resource. Farther up in the watershed, in the vicinity of Sullivan in Washington County, deposits of high-grade iron ore, occurring at depths between 1,500 and 3,000 feet, are about to be exploited. In the southwest section of the sub-basin near the juncture of Crawford, Dent, and Iron Counties, production of lead from the recently opened Viburnum Mines has begun, and explorations for lead, copper, and iron are continuing throughout the basin. Silica sand from the Ordovician St. Peter sandstone is quarried at Pacific, Missouri, and some building stone is produced from the Roubidoux sandstone for local consumption. The limestones of the Plattin, Kimmswick, and St. Louis formations are quarried extensively for concrete aggregate, roadstone, and agricultural lime. The mineral resources of the Meramec Basin, along with current explorations and development, are covered in APPENDIX J of this report. Locations of mines, quarries, and sand and gravel pits are shown on PLATE D-1.

9. STRATIGRAPHIC SUCCESSION

The stratigraphic succession ranges in age from Precambrian to Pennsylvanian, with rock types of granite, felsite, dolomite, limestone, sandstone shale, and clay represented. Small amounts of coal are associated with the Pennsylvanian deposits in sinks and depressions, and remnants of siliceous gravels, considered to be Tertiary in age, cap a restricted upland north of Pacific in St. Louis County. Loess and loess-derived soils occur at the northern boundary of the basin and at the mouth of the Meramec River. A generalized stratigraphic sequence of the consolidated rocks is shown on the legend of PLATE D-1.

10. SURFACE ROCK

a. Precambrian granite. Exposures of the granite are limited within the basin and consist of pink to gray, massive, medium-grained rocks low in iron and dark mineral content. No structures are planned which involve the granite, nor is it currently being quarried within the basin as a source of construction materials.

b. Precambrian felsite. The felsite as seen in the Meramec Basin is a reddish-dark-gray rhyolite with few feldspar or quartz phenocrysts. The rock is hard and somewhat brittle, exposures usually showing sharp angular outlines except where waterworn. Jointing is close spaced, and most outcrops reflect this feature. The high "knobs" and "mountains" in the upper Big River watershed are carved in this rock, and it is the surface rock of quite a few valley walls and "shut-ins" in this area.

c. Cambrian Lamotte. Exposures of this predominantly quartzose sandstone are limited to the drainage areas of Terre Bleue and Cedar Creek, tributaries of the Big River. The Lamotte here is reddish-gray, comparatively well indurated, medium- to coarse-grained sandstone. It is well bedded, with a few thin clay layers occurring between beds. No chert was observed in the outcrops. Except where tight cementing has occurred or where topographic or structural conditions are unfavorable, the Lamotte has been described as an aquifer yielding abundant supplies of water. Thicknesses up to 500 feet have been recorded for this formation in well logs.

d. Cambrian Bonneterre. The Bonneterre is a gray to gray-brown, medium-bedded, chert-free dolomite, containing many small dolomite- and calcite-lined vugs. In some areas, beds of limestone occur within the dolomite. As noted elsewhere, this formation is an important host rock for lead deposits and is quarried for crushed stone. Locally, a chocolate-red, fat soil is derived from Bonneterre weathering. In the "Lead Belt", the formation has an approximate thickness of 400 feet.

e. Cambrian Davis. The Davis formation consists of a complex of thin-bedded dolomitic limestones, green to brown plastic shales, slabby beds of calcareous sandstone or siltstone, and beds of limestone conglomerate. It is glauconitic in part and almost free of chert. It is the least resistant of the Cambrian formations, and soils derived from the Davis formation have a flaky and ashy texture. The thickness of the formation is variable, but averages about 170 feet.

f. Cambrian Derby-Doerun. Thin to medium beds of argillaceous, buff dolomite, alternating with thin shale and siltstone, are exposed in the upper drainage basin of Big River as the Derby-Doerun formation. These beds, along with the underlying Davis formation, are the only conspicuously shaly formations of the Missouri Cambrian. The thickness is variable, averaging some 150 feet.

g. Cambrian Potosi. This massive, brownish dolomite contains considerable quartz druse associated with chert. It is consistently porous and vuggy and contributes moderately to large quantities of groundwater. Many small springs issue from this formation, and

commercial barite deposits occur in the distinctive red, sticky, residual clay developed in southern Washington County. The gravels of the middle Big and Meramec Rivers contain a large percentage of cherty quartz druse derived from this formation. The average thickness is 200 feet, but deep wells have penetrated over 300 feet of rock referred to the Potosi formation.

h. Cambrian Eminence. An overwhelming percentage of the major caves in the Meramec Basin is developed in the massive, coarse-grained, cherty dolomites of the Eminence formation. Several large and many smaller springs issue from these rocks which form the valley walls over a considerable area of the Big and Meramec watersheds. Groundwater occurs in quantity in crevices and openings in the dolomite, and small city wells have tapped this aquifer for municipal supplies. The Eminence has a thickness of 200 to 250 feet.

i. Ordovician Gasconade. The brownish-gray, cherty dolomites of the Gasconade form many of the bluffs along the streams of the basin. Some caves and the majority of the larger springs of the watershed occur in this formation. The lowermost part, designated the Gunter Member, is a persistent sandstone or arenaceous dolomite and is generally a reliable source of groundwater. The weathering of this 300-foot thick formation produces a very cherty residuum, and gentle slopes and hillsides underlain by the Gasconade have a conspicuous, light-colored chert mantle.

j. Ordovician Roubidoux. Sandstone is the dominant constituent of the Roubidoux in the Meramec Basin, with subordinate cherty dolomites. The sandstone is fine grained, massive to well bedded, has a reddish to gray cast on surface exposures, and is commonly cemented with dolomite. The dolomite is sandy, finely crystalline, and contains beds of banded, oolitic, sandy chert. The formation is commonly found capping the upland divides, and its total thickness in the basin is usually less than 100 feet. Domestic and larger supplies of groundwater can be obtained from Roubidoux sandstones.

k. Ordovician Beekmantown. A thick (550 to 600 feet) section of dominantly argillaceous dolomites underlies a large area in the north and northeastern sections of the Meramec Basin. The stratigraphic interval from the Jefferson City through the Cotter, Powell, and Smithville formations is regarded as equivalent to the Appalachian Beekmantown, and these formations, with the exception of the Smithville which is not known to occur in the basin, are referred to as Beekmantown in this report. The Beekmantown consists of brownish, argillaceous dolomites, with beds of sandstone, shale, and cherty dolomites. Sequence is seldom duplicated at different outcrops, and individual formations are difficultly differentiated. Fine crystalline,

argillaceous dolomite called "cotton rock" is characteristic. Except for occasional durable ledges, the formations are relatively soft and easily weathered. While the oolitic cherts are somewhat diagnostic, the formations are not heavy chert bearers. Small supplies of groundwater are obtained from sandy layers and crevices in the dolomite, and limited amounts of building stone and crushed stone, including agricultural magnesium-lime, are quarried from the Beekmantown.

l. Ordovician St. Peter. The St. Peter is a massive, pure sandstone composed of fine-grained, rounded, and frosted quartz grains. It occurs in a narrow belt extending northwest and southeast of Pacific, Missouri. Its entire thickness of 60 to 80 feet is generally permeable, and fresh exposures are soft and friable. As it is a source of glass sand and abrasives and is a good aquifer, it is an economically important formation in the basin. Beneath the St. Peter in Jefferson County, thin sandy dolomites of the Everton formation occur in increasing thicknesses southward. The Everton is grouped with the St. Peter on PLATE D-1.

m. Ordovician Joachim. The Joachim consists of some 80 feet of yellowish-brown, argillaceous dolomites occurring in a belt parallel and east of the St. Peter. The rocks are relatively weak and less resistant to erosion and, being chert free, leave a clayey or silty residuum. Small amounts of water can be obtained from crevices and solution openings in the dolomite.

n. Ordovician Plattin. The Plattin formation consists of some 140 feet of dense, very fine-grained limestone occurring in the belt of Ordovician rocks east of Pacific, Missouri. The limestone weathers to a system of narrow, tubular openings, giving a worm-eaten appearance. As the limestone is hard and durable, it is quarried for use as concrete aggregates.

o. Ordovician Decorah. The Decorah is a thin formation consisting of interbedded thin limestones and shales. It is a poorly resistant formation, and outcrops are limited.

p. Ordovician Kimmswick. The Kimmswick is a massive, coarse-grained, crystalline limestone, attaining a thickness of 150 feet. It is typically white to light-gray and very pure. Overlying the Kimmswick intermittently is a coarse-grained, argillaceous limestone, several feet in thickness, which has been named the Cape formation. A little groundwater from crevices and solution openings has been obtained from these formations.

q. Ordovician Maquoketa. The Maquoketa consists of from 30 to 60 feet of thinly laminated, silty, and calcareous shales of a dark color.

It is a non-resistant, air-sensitive formation, and outcrops are few.

r. Mississippian rocks. Mississippian rocks underlie that portion of the Meramec watershed extending from the belt of upper Ordovician rocks to the Mississippi River. Many of the formations have a limited outcrop, while others are areally extensive, and a few are economically important. Several non-persistent formations, including the Grassy Creek shale, Glen Park limestone, and Bushberg sandstone, are presently classified as unassigned Devonian or Mississippian. These formations and the Kinderhookian Chouteau limestone crop out in the vicinity of Castlewood along the Meramec River. The Fern Glen calcareous shale and limestone also outcrop at this locality. Other Mississippian formations underlying the lower Meramec Basin include, in ascending order:

(1) Burlington-Keokuk - About 175 feet of light-colored, coarsely crystalline, crinoidal, and cherty limestone.

(2) Warsaw - Some 80 to 100 feet of dark shale and shaly, dolomitic limestone.

(3) Salem - About 150 feet of argillaceous limestone, locally dolomitic, shaly, oolitic, and cherty; quarried for crushed stone in St. Louis County.

(4) St. Louis - Up to 250 feet of dense lithographic to finely crystalline limestone in which chert is sparingly developed. Locally thin shales and siltstones are encountered. The limestone is quarried in the St. Louis area for cement manufacture and concrete aggregate.

s. Pennsylvanian rocks. The Pennsylvanian system underlying the uplands in the upper Bourbeuse watershed and in isolated patches elsewhere in the Meramec Basin is represented by shale, sandstone, clays, and a little coal. Much of this rock occupies sinks and depressions developed on the Cambro-Ordovician surface. The predominant and most conspicuous lithology is the fire clay, which is of the plastic to flint variety, white to light-gray in color, with reddish and purple tints. This clay is mined in surface pits and trucked to stockpiles and refining plants. None of the small patches of coal is currently being mined.

11. GROUNDWATER CHARACTERISTICS

The ability of the geological formations to store, transmit, and yield water is a function of many variables in addition to the physical

characteristics of the rock. Some of the additional variables include topography, hydraulic head, and geological structure. However, in the basinwide distribution, potential aquifers may be expected to yield certain quantities of water. A general summary of formations and their normal characteristics follows.

a. Recent alluvium. Large yields may be obtained where the alluvium is thick. Water may require iron removal locally.

b. Pennsylvanian strata. Very little water is obtained from these rocks.

c. Mississippian strata. Small amounts of water are available, but the yield is selective and spotty.

d. Ordovician system.

(1) Maquoketa - No water available.

(2) Kimmswick to Joachim - Small amounts can be obtained, but water is usually mineralized.

(3) St. Peter - Good aquifer for domestic and municipal supplies. Water may be mineralized.

(4) Beekmantown - Small amounts available; may be mineralized.

(5) Roubidoux - Good domestic and municipal supplier.

(6) Gasconade - Good to fair municipal supplier.

(7) Gunter Member - Yields domestic and municipal quantities.

e. Cambrian system.

(1) Eminence and Potosi - Yield moderate to large supplies.

(2) Derby-Doerun to Bonneterre - These formations generally yield only small amounts of water.

(3) Lamotte - Yields moderate to large amounts.

f. Geographic characteristics. Certain formations are tapped in various basin sectors and provide the major source of groundwater. The sectors and aquifers are:

(1) Southeast basin - In Washington and St. Francois Counties, the Potosi and Lamotte formations are good aquifers, with some yield coming from the Bonneterre.

(2) Central basin - From Rolla to Pacific, Missouri, the Roubidoux, Eminence, and Potosi formations yield most of the groundwater.

(3) Northern sector - Small supplies have been obtained from the Roubidoux, with larger amounts coming from the Eminence-Potosi at greater depths.

(4) Northeastern sector, east of Pacific, Missouri - Large yields are obtained from the St. Peter.

(5) Northeastern sector, east of Eureka, Missouri - Small yields are available from the Mississippian limestones.

g. Municipal well characteristics. To more fully describe groundwater characteristics of the formations, the following municipal well statistics are outlined. Data were obtained from the Missouri State Geological Survey.

(1) Rolla Well No. 5 - Penetrated Jefferson City through Elvin formations, at total depth of 1,078 feet; 230 feet of casing set; static water level 165 feet; yield 540 G.P.M.; drawdown 80 feet.

(2) Salem Well No. 2 - Penetrated Gasconade through Lamotte formations, at total depth of 1,470 feet; 400 feet of casing set with 200 feet of liner through Davis shale; static water level 34 feet; yield 250 G.P.M.; drawdown 166 feet.

(3) St. James Well No. 2 - Penetrated Jefferson City through Elvin formations, at total depth of 1,100 feet; 295 feet of casing set; static water level 198 feet; yield 360 G.P.M.; drawdown not reported.

(4) Bourbon Well No. 2 - Penetrated Roubidoux through Potosi formations, at total depth of 501 feet; 180 feet of casing set; static water level 185 feet; yield 73 G.P.M.; drawdown unknown.

(5) Sullivan Well No. 2 - Penetration is Gasconade through Elvin formations, at total depth of 850 feet; 345 feet of casing set; static water level 160 feet; yield 420 G.P.M.; drawdown 100 feet.

(6) Owensville Well No. 2 - Penetration is Jefferson City through Potosi formations, at total depth of 962 feet; 430 feet of

casing set; static water level 198 feet; yield 79 G.P.M.; drawdown 180 feet.

(7) Farmington Well No. 6 - Bonneterre through Lamotte penetration; total depth 638 feet; 200 feet of casing set; yield, before shooting Lamotte, 80 G.P.M.; yield, after shooting Lamotte, 162 G.P.M.; drawdown 222 feet.

The groundwater characteristics at proposed reservoir sites are discussed in SECTION IV of this appendix.

12. STRUCTURE

a. General. The controlling structural feature affecting the Meramec Basin is the Ozark uplift. Rocks of the basin lie on the northern flank of the uplift and dip gently to the north and northeast. Adjacent to the igneous knobs in the southern portion, the rocks dip sharply away in all directions, and, at the mouth of the watershed, the dip again is increased, plunging towards the Illinois structural basin to the east. In the upper Bourbeuse drainage basin, the rock slope is more gentle. Superimposed on the broad rock slopes are occasional low folds and structural highs; however, no folded structures of any great magnitude are known. Irregular subsidence on portions of the Roubidoux capped upland has resulted in discontinuous low swells and depressions, thought to be caused by local dissolving of the underlying soluble rocks.

b. Faults. Several rather well-defined fault systems of considerable length, but usually small displacement, occur in the basin. See PLATE D-1. Some of these normal faults have been active to a minor degree, as indicated by seismic determinations at St. Louis University. Drag folds are associated with a few faults, while others appear to be the result of high-angle shear with little disturbance of affected beds. An extremely complex feature, consisting of a circular, highly deformed area on Crooked Creek, with high-angle faults of large displacement, has been interpreted to be the result of either a subterranean explosion or the impact of a meteorite. From the limited evidence available, most fault planes are judged to be tight and well healed. Exceptions may be noted, however, as the association of McDade Spring with the Cuba Fault zone demonstrates.

c. Joint systems. The topography, the drainage patterns of the streams, and the surface configurations of rock bluffs in the basin show a dependency on the joint fractures exhibited in the rocks. Closely spaced joints, probably resulting from cooling tension, are prevalent in the outcropping felsites, and columnar hexagonal jointing is sparingly developed. Sheet jointing in the granite is very

pronounced just beyond the watershed boundaries. Other than the above jointing types in the igneous rocks, most joints are the result of forces due to faulting or development of the broad folds in the sedimentaries. Tension joints resulting from drying or shrinking are rare. The delineation of the direction of the major sets of joints varies with local conditions, but the predominant alinement appears to be NE-SW and NW-SE. Many of the joint fractures are healed with dolomite and calcite.

SECTION IV - GEOLOGY OF MAIN STREAM RESERVOIRS

13. PINE FORD RESERVOIR (2A)

a. Borings. Subsurface explorations included four shallow core borings and seven borrow borings, the logs of which are shown on PLATE D-6. Bedrock penetrated along the proposed axis consists of hard, vuggy dolomites of the Gasconade formation, moderately affected by solution. The beds of coarse-grained dolomite are relatively thin, contain nodular, bluish-grey chert, and weather to a sandy texture. The majority of core recovered is weathered and fractured. Depth to rock beneath the flood plain is indicated to be 25 feet. On the valley slopes and abutments, rock was encountered at depths less than 15 feet.

b. Surficial rock. There are no significant rock outcrops on either of the moderately sloping valley walls at the proposed axis. Upstream, however, the river flows against many near-vertical rock bluffs capped with sandstones of the Roubidoux formation. On the right bank of the river, approximately 1 mile upstream of the axis, a sizeable cavern, having an entrance 10 by 30 feet, extends into the rock an unknown distance. Farther upstream at the narrow divide on the river loop, considerable solution pockets and caves with openings up to 4 feet in cross section taper back into the dolomite and remain open to the limit of observation.

c. Faults. In the reservoir area, across from the mouth of Ditch Creek, there is evidence of a small normal fault trending NW-SE. The displacement is small, and the fault zone visible is tight. The only other indication of faulting occurs in the upper reaches of the reservoir, where the extensive and complex Vineland Fault zone cuts across the pool area. The northeastern side is downthrown and results in successively older rocks forming the bedrock surface.

d. Groundwater. An analysis of 44 water well logs shows that limited yields of 5 to 15 G.P.M. are obtained from the Potosi-Bonneterre at depths of 100 feet. Deeper wells (200-400 feet) obtain 20 to 50 G.P.M. from the Potosi down through the Lamotte. The well records disclose groundwater levels higher than adjacent streams.

e. Mineral deposits. Deposits of barite are known to be located in the reservoir area, but current mining operations are situated above the flood control pool elevations. See APPENDIX J. The area is also underlain by lead-bearing dolomites.

f. Auxiliary dam. An auxiliary power dam and reservoir on a tributary ravine just downstream of the main dam were considered.

Bedrock conditions are similar to the main dam, with rock showing at the surface of several natural drains. The perimeter of the studied power pool would require considerable length of tie-in dikes to achieve maximum storage. As the residual soil capping the narrow divides beneath these dikes is pervious, an impervious earthern cutoff is proposed. Rock outcroppings on the ravine slopes are scarce; however, indications are that the depth to rock is minimal.

g. Conclusions.

(1) No indications of adverse geologic factors of a magnitude to eliminate the feasibility of this project have been disclosed by present investigations.

(2) Depths to rock are not excessive. It is estimated that rock is somewhat weathered and permeable along the power pool rim.

(3) The presence of permeable deposits in the valley flat would require a cutoff to insure positive control of seepage.

(4) Normal grouting programs should be required along the center line of both dams and at the narrow ridge at the river loop neck, as well as a shallow curtain beneath the earth cutoff for tie-in dikes of the power pool.

(5) Faulting in the reservoir area does not appear to present leakage problems. The trace of one fault observed in the field was very tight. Minor activity along the Vineland Fault system was reported in 1946.

(6) The construction of the project would eliminate the future development of barite leases and might adversely affect exploration of lead properties.

(7) Foundation rocks of the Gasconade formation are strong, hard, and durable and are not known to contain soft or plastic zones. Bedding planes are tight, and jointing is widely spaced. The dolomite does contain soluble layers, which would require careful explorations in advanced studies.

(8) Water well data show groundwater gradients indicative of reasonably tight valley walls.

14. WASHINGTON PARK RESERVOIR (5)

a. Borings. Boring data shown on PLATE D-7 indicate moderate depths to rock along the axis of the proposed dam, but the surface rock is somewhat porous and weathered.

b. Surficial rock. At the studied site, the right valley wall is a vertical rock bluff carved in the Potosi dolomite and extending upward directly from the water's edge. The left side of the stream contains a gravelly, clay-filled flood plain and a moderately steep slip-off slope produced by lateral degradation. Above the damsite, the flood plain is well developed and bordered on at least one side by high vertical rock bluffs.

c. Faults. Several small solution pockets show in the vertical rock bluffs, but no indications of major solution zones were observed. The Potosi formation here exposed is a hard, somewhat vuggy, massive, brown, cherty dolomite, with the typical quartz druse only sparingly developed. The beds are essentially horizontal, and jointing appears to be widely spaced. Bedding planes are irregular and ill-defined. No soft or questionable zones were observed and there are no known faults at the damsite or in the reservoir area.

d. Groundwater. Limited water well data indicate that from 5 to 15 G.P.M. can be obtained at depths of 100 feet from the Potosi formation. Highest yield noted is 40 G.P.M., while one well driven to 394 feet obtained only 15 G.P.M. Two fairly large springs in the headwaters and numerous small springs along the valley contribute to the flow of Mineral Fork. This consistent flow, compared to the drainage area, indicates that bedrock seepage is negligible at the damsite.

e. Mineral deposits. Mineral resources of the reservoir area are limited to several small hand-operated barite pits and gravel bars worked sporadically for very local use.

f. Conclusions.

(1) The foundation rock, as revealed by the exploratory borings, occurs at moderate depth along the proposed axis. The rock as observed in the right bluff is hard and competent.

(2) Because of the porous nature of the bedrock, a normal grouting program should be required across the valley section.

(3) An impervious cutoff to bedrock will be required to prevent underseepage through the flood plain sands and gravels.

(4) Water wells of the area and surface flow indicate a rather tight bedrock valley.

(5) No important mineral resources would be inundated.

(6) There are no known geological features that would classify this site as unsatisfactory.

15. **IRONDALE RESERVOIR (9)**

a. Surficial rock. The site is in the foothills of the St. Francois Mountains, and Precambrian igneous rocks are prominently displayed as knobs or bare to partly forested hills. The river at the damsite has cut a steep valley in the resistant rhyolite, and both valley walls and the streambed are essentially in bedrock. A very thin gravel covers the streambed with rock crags protruding through. Valley slopes are partly forested between steep to vertical rock outcrops. On the left abutment, contact of the igneous rhyolite body and the adjacent Bonneterre dolomite occurs in the vicinity of boring I-4. See PLATE D-8. The dolomite here is essentially horizontal, occurs in thin beds, and is overlain with about 10 feet of fat clay. Along the main valley section, the rhyolite is dark purple, very fine grained, contains occasional large feldspar crystals, and is complexly jointed and fractured. The rock is very hard, and outcrops, not influenced by water erosion, are sharp and angular.

b. Sinkhole. Upstream of the proposed axis on the left abutment there is located a large, very free-draining sinkhole dissolved in the Bonneterre. This sink is said to drain near river level about a mile upstream of the axis. There is no indication of subsurface drainage at the axis, but this feature would be checked in future studies.

c. Mining operations. An old iron mine shaft was found just upstream of the axis on the same abutment as the sink. It is of unknown depth, waterfilled, and from several observations appeared to be tight. An abandoned strip iron mine is located nearby and practically on the axis. The diggings were shallow, and no problems are anticipated here.

d. Groundwater. Twenty-one water well logs show yields of 5 to 15 G.P.M. from Bonneterre-Lamotte at depths of 50 to 150 feet. No record of large-yield wells in the reservoir area could be found.

e. Conclusions.

(1) Preliminary investigations indicate a geologically feasible site.

(2) No adverse factors were encountered, but subsurface drainage in the rhyolite and faulting in the reservoir area should be investigated in future studies.

(3) Required rock excavation should be minimal but costly in the very hard rhyolite.

(4) A normal grouting program would be advisable in the dolomite section along the axis.

(5) Iron was formerly mined in the area and explorations for lead have been made. However, there are no known mineral resources actively being exploited.

16. MERAMEC PARK RESERVOIR (17)

a. Borings. The largest reservoir in the system currently being studied would be located in Meramec State Park near Sullivan, Missouri. The main dam location was explored in some detail during previous studies. Selected boring logs of these previous studies and logs of borings drilled for hilltop power reservoir are shown on PLATES D-10, D-11, D-12, and D-17.

b. Bedrock. Dolomites of the Gasconade and Eminence formations underlie the valley walls and streambed at the main damsite, and estimated depths to bedrock are shown on the typical sections of PLATE E-11, APPENDIX E. Drilling has indicated variable depths to rock along the summits of the valley divides, due mostly to differential weathering of the soluble dolomite. Both of the surface formations contain considerable chert and the residuum is granular and pervious. Transition zones from weathered to firm rock can be rather large. The dolomite bedrock, where unweathered, is hard and strong and is not known to contain soft or plastic zones. A thin-bedded, somewhat shaley phase, occurring near the contact of the Gasconade and Eminence formations, is always undercut in natural exposures and is evidently the weakest rock known in the area.

c. Caves. As shown on PLATE D-1, the area contains a number of caverns dissolved from the soluble dolomites. At least two of these caves cross or very closely approach the axis of the proposed main dam on the left abutment. A small spring or cavern stream exits from the left rock bluff near the water's edge. A detailed study of the possibility of water flooding the downstream commercialized Fisher Cave through subterranean fissures was undertaken. Maps of the cave were obtained from the Missouri State Geological Survey and were superimposed on a series of cross sections of the downstream topography. From this study, it is concluded that any leakage through bedrock would find surface relief at an intervening ravine and the cavern would not be affected.

d. Faults. A major fault system, the Leasburg Fault, crosses the extreme upper end of the reservoir. The trace of this fault was not observed in the field and no other faults have been located.

e. Mineral deposits. Shallow, sink type deposits of iron were formerly mined in the reservoir area. No currently active mines of this type are known, but deep-seated iron ores are presently being mined at Pea Ridge, to the east of the reservoir area.

f. Hilltop power pool. At the hilltop power site, the dam would cross a steep side ravine, whose confining slopes expose nearly continuous rock outcrops beneath a soil thick enough to support trees and other vegetation. The bottom of the ravine contains some 20 feet of alluvium, while the underlying Eminence dolomite is much weathered for an additional depth of 10 to 15 feet. Borings on the power pool rim indicate weathered rock to vary from 15 to 50 feet below ground surface. In the northwest rim of the power pool, the existence of a cave with connection to a large sink has been observed. A field traverse of the pool slopes has also shown many ledges and undercut rocks leaking water, while the cherty, granular residuum overlying rock on the crests has been shown by explorations to be very pervious. The presence of these leaky subsurface conditions would require considerable remedial measures in the forms of grouting, concrete cave filling, saddle dams with impervious cutoffs, and sealing leaking pool zones.

g. *Reregulating dam*. The site of the low reregulating dam contains a rock bluff on the left bank and a very sandy, rather extensive flood plain on the right. The only problem evident here is the stabilizing of the sandy right bank to prevent erosion due to infrequent flooding over the weir.

h. Groundwater. An analysis of 72 well logs in the area shows that domestic water yields of 10 to 20 G.P.M. are obtained at depths from 150 to 250 feet. The major aquifer is the Gunter Member of the Gasconade, with some yield from the Eminence-Potosi. Larger yields (50 to 280 G.P.M.) are obtained by penetrating the Eminence and going to the Lamotte. Depths of larger wells range from 300 to 900 feet. As determined from wells and borings, water levels are rather low in both bedrock valley walls.

i. Conclusions.

(1) The cherty dolomites involved in all structure foundations are hard, competent rocks when fresh and unweathered and contain no known soft or plastic zones. A persistent, thin shaley zone, frequently undercut, occurs near the contact of the Gasconade and Eminence.

(2) The existence of permeable strata, solution zones, caves, and sinks in the areas of the reservoirs and at the damsites would require additional detailed exploration during future studies.

(3) Commercially operated caverns downstream of the dams and at the upper end of the main reservoir would not be adversely affected by construction of the project.

(4) The Leasburg Fault was reported as being active (1943), producing moderate earthquake intensities in the area.

(5) Depth to bedrock and depth of weathering are considerable and erratic along the crest of the power pool.

(6) The nature of the solutionized rock indicates a grouting curtain across the entire valley alinement of both dams. Boring and well data indicate a heavy grout take.

17. SALEM RESERVOIR (27)

a. Borings. Data shown on PLATE D-13 indicate a deep, gravelly, clay residuum overlying bedrock on the right abutment above the 1,000-foot level. Below this, rock appears at more moderate depths.

b. Surficial rock. Topography of the area is rough and severely dissected. The flood plain below the proposed axis widens considerably, and, immediately above the damsite, it is similarly abnormally wide. The left abutment is cut in a near-vertical rock bluff of Gasconade and Eminence cherty dolomite. Rock outcrops are scarce on the right bank, which extends through pastureland of a fair slope to higher timber-covered uplands. Limited bottomlands are very gravelly, as is the streambed itself.

c. Bedrock. Rock is believed to lie at a depth of 20 feet below the valley section of the power pool and some 5 feet on the valley slopes. An estimated 25 feet of residual soil and weathered rock overlies the Gasconade dolomite on the power pool perimeter. Fragments of Roubidoux type sandstone lie scattered along this perimeter.

d. Caves. Gasconade and Eminence cherty dolomites are exposed in the left bluff, which contains at least two sizeable caverns. One is located approximately 150 feet upstream of the axis, with an entrance at about elevation 1,020 m.s.l. The other is found about the same distance downstream but at a much lower elevation, say 920 to 940. At least seven other caves are known to occur in the main reservoir area. No indications of cavernous conditions were observed in the

power pool area. However, a single undercut dolomite ledge was consistently noted in ravines along the valley slopes and appeared to be leaking slightly.

e. Groundwater. Several small springs issue close to stream level in the main reservoir area and directly downstream of the proposed axis. The joint controlled drainage in this portion of the Meramec would indicate that the formations are well jointed and that enlargement by solution has taken place in both these and the bedding planes. Limited water well data at this site indicate that low yields of 5 to 10 G.P.M. can be obtained from Gasconade-Eminence formations at depths averaging 200 feet.

f. Mineral deposits. Mineral resources in the reservoir area include low-grade, surface iron deposits and sand and gravel. None of the iron has been mined for many years and sand and gravel deposits are dredged or draglined only occasionally for very local use.

g. Conclusions.

(1) Depths to bedrock are not excessive along the valley sections of the main and power dams, but residuum and weathered rock along the reservoir rims are expected to be somewhat deep and erratic.

(2) Due to the soluble nature of the dolomite, grouting programs would be required along the valley sections of both dams and to cut off the persistent leaking ledge in the power pool.

(3) Conditions and subterranean outlets of caverns should be thoroughly explored in later studies. For purposes of this study, all caverns would require concrete sealing.

(4) No mineral resources are being actively exploited in the reservoir area.

(5) There is no evidence of faulting in the reservoir area.

(6) Foundation rocks would be sufficiently strong to support the structures, and there is no indication of the presence of soft, plastic, or unsuitable rock.

18. UNION RESERVOIR (29)

a. Borings. This site was explored in some detail during earlier studies, and selected borings and logs are shown on PLATES D-14, D-15, and D-16.

b. Surficial conditions. Topographically, the damsite consists of a steep left valley wall, containing many rock exposures, a very narrow flood plain, a low terrace, and a moderately steep right abutment exposing few rocks. The river veers to the south directly above the axis, and the pool area is more severely dissected than many upper reaches of this river.

c. Bedrock. Bedrock underlying the selected axis is cherty dolomite of the Gasconade formation, and depths to rock are moderate along the valley section and lower abutment slopes. See PLATE D-15. On the crests of the abutments and on the reservoir perimeter, weathered soft dolomites and sandstones of the Roubidoux attain a thickness of some 60 feet, which in turn overlie the relatively unweathered and firm Gasconade.

d. Caves. Although no cavernous conditions were encountered in the borings or observed in the field, localized zones affected by solution and small cavities occur sparingly and widely dispersed throughout the rock section. The upper 10 to 20 feet of the rock on the valley slopes are weathered in varied degrees, but no pronounced or continuous zones of soft or plastic material were observed at depth.

e. Faults. An offset of the Leasburg Fault system cuts across the rocks underlying the upper reservoir, and above this fault the proposed reservoir would be underlain by argillaceous dolomites of the Jefferson City formation.

f. Groundwater. Investigations performed during earlier studies indicate that the water table is deeply buried in the left abutment and less deeply in the right abutment. The slope of the water table appears to flatten out in the vicinity of the Roubidoux-Gasconade contact. A study of 59 wells in the reservoir area showed moderate yields (10 to 20 G.P.M.) from the Gasconade at depths averaging some 200 feet. No large or moderate-sized springs were observed in this reach of the Bourbeuse River.

g. Mineral deposits. There is at least one known deposit of refractory clay within the impoundment limits. A discussion of problems concerning clay resources affected by reservoir construction is contained in APPENDIX J. The majority of currently active clay pits occurs on high ground above flood control pool elevations.

h. Conclusions.

(1) Depths to firm rock are not excessive under the lower slopes of the abutments, but soft, fractured, and weathered rock occurs on the crests to thicknesses of 60 to 90 feet.

(2) Other than the top weathered rock, no zones of soft or plastic material were found in the underlying rocks.

(3) A grouting program would be required to reduce and control the rate of seepage through the foundation rocks.

(4) Refractory clay is the principal mineral resource of the reservoir area.

(5) The structures proposed at this site appear to be geologically feasible, with no indications of prohibitive, costly remedial measures.

(6) An impervious cutoff to bedrock will be required.

19. **VIRGINIA MINES RESERVOIR (40)**

a. General. Bedrock underlying the majority of the damsite and reservoir consists of cherty dolomites of the Gasconade formation. A high rock bluff forms the right abutment, while more gentle slopes interrupted by a few rock ledges rise from the limited flood plain on the left side of the river. Boring data show moderate depths to rock, with the dolomite being somewhat weathered and open. See PLATE D-9. Overhanging ledges and small solution openings are common but no sizeable caverns were observed in the damsite area. Sandstones and dolomites of the Roubidoux cap the uplands, and in the upper reservoir Indian Creek Arms the Eminence dolomite is the surface bedrock.

b. Faults. As shown on PLATE D-1, a fault has been traced by indirect methods across the middle of the proposed pool. In addition to this fault, there is evidence in the form of discrepancy in rock contacts of a fault cutting rocks near the dam axis.

c. Mineral deposits. Remains of filled shafts, smelters, and tailing piles are concentrated on the left upland some distance from the left axis termination and downstream thereof. Lead and barite deposits are known to underlie the reservoir area. However, no currently active mining operations will be affected by the construction of the reservoir. An active sand and gravel pit is operating downstream of the axis at the Highway 30 crossing.

d. Groundwater. An average yield of 10 to 25 G.P.M. of water is obtained from wells penetrating the Roubidoux and Gasconade at depths of 100 to 300 feet. The 54 well logs studied showed that larger yields (20 to 30 G.P.M.) were obtained by drilling through the Eminence and Potosi at depths exceeding 300 feet.

e. Conclusions.

(1) Depths to firm rock are not excessive and there are no known soft or plastic zones beneath weathered rock.

(2) The dolomite foundation is shown to contain open zones which will require a seepage control grouting program.

(3) No active mining operations are underway in the area. From all data available, the existence of the old mines near the axis will not affect the construction or operation of the proposed dam.

(4) Future investigations should be undertaken to study faulting conditions at the damsite.

(5) No extensive caverns or large springs are known to occur in the project area.

SECTION V - GEOLOGY OF TRIBUTARY RESERVOIRS

20. HUZZAH CREEK RESERVOIR (I-14)

a. Site. The damsite is located on Huzzah Creek, 1 mile southeast of Davisville. Both abutments are steep rock bluffs. There is a limited gravel-choked flood plain on the left side of the stream. The reservoir area is steep and roughly dissected. The stream has a steady, perennial, spring-fed flow.

b. Geology. The abutments and reservoir are underlain by Potosi dolomite. The depth to firm rock beneath the flood plain is estimated to be in the order of 10 feet. There are no sizeable caverns in the reservoir area. There are many small springs immediately upstream from the damsite. An abundance of quartz druse indicates deep weathering on the reservoir rim. The vicinity of the reservoir is undergoing intense mineral exploration. Woodlock, a sizeable spring, is located downstream of the damsite. No faulting or active mines are known to exist in the impoundment area.

c. Conclusions. The reservoir rim near the right abutment should be drilled to investigate possible leakage conditions. Confidential mine leases may make the land acquisition expensive. See APPENDIX J. Investigations revealed no additional data that would indicate the site as geologically unfeasible.

21. COURTOIS CREEK RESERVOIR (I-15A)

a. Site. The damsite is located on Courtois Creek just below the junction with Hazel Creek, some 4 miles southeast of Berryman. The right valley wall is a high, nearly vertical rock bluff. The left bank carries an overgrown gravelly flood plain and a low, somewhat terraced rock bluff. The creek carries a considerable flow with a good current.

b. Geology. The site is underlain by slightly solutionized cherty dolomites of the Eminence formation. A complex faulted section of the Palmer Fault zone lies in the reservoir area and downstream from the axis. Deposits of barite are known to underlie the reservoir area, but there is no current active mining. A few springs are known to exist above the axis. Limited well data indicate a high groundwater gradient in the valley slopes. No caves were discovered.

c. Conclusions. The left abutment may be affected by pinnacle weathering, making rock excavation somewhat difficult. A normal grouting program should be sufficient to control seepage. No leakage is anticipated due to faulting and the faults are considered to be inactive. There is no apparent adverse geological feature other than the suspected pinnacle weathering.

22. PEAVINE CREEK RESERVOIR (I-21)

a. Site. The damsite is located in the northwest corner of the basin on Peavine Creek, which is a tributary of Dry Fork of the Bourbeuse River. The damsite is relatively wide, with gentle sloping abutments and a well-developed, cultivated flood plain. The stream channels are choked with sand and gravel, rock exposures are limited, and streams carry intermittent surface flow.

b. Geology. The bedrock consists of argillaceous dolomite, chert, and a few sandstone beds, all assigned to the Jefferson City formation. A large active sink is present several hundred feet downstream of the damsite on the right bank. There is no evidence of faulting in the reservoir area. Two water wells indicate groundwater levels are below the stream level. In this portion of the valley, there are no known mineral resources other than sand and gravel.

c. Conclusions. Additional studies will be required to determine whether surface flow is diverted to underflow in gravel or lost to bedrock zones and solution passages. The leakage problem is the major adverse geological feature of this site.

23. LITTLE DRY FORK CREEK RESERVOIR (I-23)

a. Site. The damsite is located approximately 5 miles east of Rolla on Little Dry Fork of the Meramec River. Both abutments are rather steep, with bluff rock exposures in the vicinity of the damsite. The effluent from the Rolla sewage disposal plant augments the stream flow.

b. Geology. The rock exposed consists of alternating sandstones, cherty dolomites, and massive sandstone of the Roubidoux formation. Well-developed prominent jointing, when weathered, results in slumped blocks and sinkhole development. Where unweathered, the joints appear to be tight. Several small springs at stream level occur in the impoundment area. There are indications of several small faults in the reservoir area, but no sizeable caverns. Wells studied show relatively high static water levels in the area.

c. Conclusions. Detailed axis studies would be required to avoid collapse structures in the sandstone at the abutments. Minor faults and joints appear to be tight and high static water levels tend to confirm this. The depth to rock does not appear to be excessive. The site is considered to be geologically feasible.

24. WEST FORK HUZZAH CREEK RESERVOIR (I-26)

a. Site. The damsite is located on the west fork of Huzzah Creek, 3 miles south of Dillard. The valley walls are high, moderately sloping hills with few rock exposures. There is a considerable flow of clear water in a channel on a narrow flood plain containing much heavy gravel. Many of the hills in the reservoir area have been cleared of timber on the lower slopes.

b. Geology. Scarce rock outcrops indicate that the valley walls are underlain by cherty dolomites of the Eminence formation. The abundance of quartz druse in the gravel of the stream leads to the assumption that the stream is cut in the underlying Potosi cherty dolomite. No caverns or evidences of faulting were discovered in the impoundment area. One of the larger springs of the basin, Howes Mill, issues from the Eminence several miles upstream of the proposed reservoir. The single well known in the area shows the static water level to be high in the valley wall. There are no known mineral resources in the reservoir lands, but active exploration is continuing in an area just southeast of the site.

c. Conclusions. Other than the possibility of thick residuum on the valley walls, there are no known geological impediments at this site.

25. SPRING CREEK RESERVOIR (I-28)

a. Site. This site is on Spring Creek, a tributary to Dry Fork of the Meramec River, some 5 miles northwest of Salem. The damsite is on a constricted section of the creek, having practically no flood plain, with a steep right abutment and a more gently sloping left abutment. The perennial flow of the stream is augmented by the effluent of the Salem sewage disposal plant and by small springs above the damsite.

b. Geology. The site is underlain at some depth by cherty dolomites of the Gasconade formation. Slumped and irregularly bedded Roubidoux sandstones cap the uplands. There are no known faults or caves in the impoundment area. The proposed reservoir is in a section where near surface iron deposits were formerly mined; however, no known mineral resources would be affected. Well data available indicate thick, cherty, clay residuum overlying bedrock in most of the area. This residuum appears to be rather tight, as the chert and sandstone fragments are incorporated in a high proportion of compacted silty to sandy, clay matrix and as the stream flow does not show any abnormal fluctuations.

c. Conclusions. Future explorations would be required to detail the depth of residuum along the axis and to confirm its relative tightness. Other geological characteristics indicate that this is a favorable site.

26. TERRE BLEUE CREEK RESERVOIR (I-30)

a. Site. Terre Bleue Creek is a tributary of the Big River. The damsite is about 8 miles east of Bonne Terre. Low rock bluffs border the narrow flood plain at the site. Topography of moderately low relief is considerably broken and becomes much flatter downstream of the proposed reservoir. The stream carries a fair flow.

b. Geology. The rock exposed at this site is quartz sandstone of the Lamotte formation. Here it is well bedded, only slightly friable, and is the only rock exposed. Clay layers a few inches thick are known in the reservoir area. Limited well data indicate the static water level to be at or near stream level. There are no known mineral resources underlying the proposed reservoir. Locally, the Lamotte has been quarried for use as a building stone and flagstone.

c. Conclusions. The presence of clay seams, the sandstone friability, and possible low water levels should be investigated in future explorations. No additional adverse geological features are known at this time.

27. REDOAK CREEK RESERVOIR (I-32)

a. Site. The valley of Redoak Creek, about 5 miles south of Gerald, is comparatively wide, with a steep left bank carrying stepped rock outcrops and a gentle right bank partially cultivated. The stream flow is very moderate over a gravel-choked bed.

b. Geology. The rocks exposed are dolomites of the Jefferson City formation. At the damsite, outcrops are overgrown and poorly visible. Upstream of the damsite on the right or west bank, the dolomite is slumped and contains many solution channels. Refractory clay deposits are known to occur in the reservoir area but none are being actively mined. There are no known faults or caves, but a few small springs were observed near stream level.

c. Conclusions. The solutional aspect of the bedrock, in conjunction with a low stream flow, indicates the need for detailed study of the foundation and reservoir bedrock.

28. LITTLE BOURBEUSE RIVER RESERVOIR (I-33A)

a. Site. About 9 miles northwest of Bourbon on the Little Bourbeuse River, this damsite is located at a sharp bend in the stream, bordered on the right by a gentle-sloping pastureland and on the left by a steep bluff with rock outcrops at the water's edge. Flow is moderate over a graveled or bedrock streambed.

b. Geology. Sandstones of the Roubidoux cap the uplands, while dolomites of either lower Roubidoux or the Gasconade form the left rock bluff and stream outcrops. No caverns are known, but this section of the Roubidoux is noted for its susceptibility to solutional activity. A small fault is known to cut the rocks at the extreme upstream end of the reservoir. Refractory clay deposits, usually above the proposed flood control pool, are the only known mineral resources that would be affected.

c. Conclusions. Detailed topographic and survey studies may result in a somewhat narrower valley section with a slight shift in axis location. At the time of these studies, the possibility of subsurface leakage would be investigated. Aside from these considerations, there is no reason to indicate that this is not a favorable site.

29. BRUSH CREEK RESERVOIR (I-35A)

a. Site. Location is on Brush Creek about 1 mile upstream from its confluence with the Bourbeuse near the Gasconade-Crawford county line. The valley is relatively wide and contains an extensive flood plain. The right bank is gently sloping and is in cultivation, while the left bank is gentle, heavily forested, and contains scattered rock outcrops.

b. Geology. Argillaceous dolomites with some sandstone of the Jefferson City formation form the bedrock surface of the damsite and reservoir area. The stream has cut a wide valley in the moderately erodible dolomites, aided at least in part by subsurface solution work. Pennsylvanian shales, clay, and sandstone cap the uplands around the impoundment area. Filled sinks and collapsed structures result from the shales, clay, and sandstone in that area. No faults, caves, or sizeable springs are known in the reservoir area. There are no known mineral deposits that will be affected. Groundwater gradients under the valley walls appear to be reasonably high.

c. Conclusions. Some beds of the Jefferson City break down rather rapidly on weathering and should be studied during the design of rock cuts and exposed slopes. Future studies should explore beneath

the proposed spillway to avoid filled sinks as a structure foundation. Evidence of water wells and observations of road cuts through these filled sinks indicate that they are reasonably watertight.

30. BOURBEUSE RIVER RESERVOIR (I-38)

a. Site. Just upstream of the Highway B crossing of the Bourbeuse River near the confluence with Lanes Fork, the damsite is located on a somewhat constricted section of the valley just below a wide flood plain area. The flow of the Bourbeuse is rather low and in Lanes Fork the flow is intermittent.

b. Geology. Rock outcrops are scattered over the gentle slopes of the region, with Roubidoux sandstone exposed at the damsite and the reservoir area underlain by dolomites of the Jefferson City formation. Pennsylvanian shales, sandstone, and clay cap the uplands and fill sink structures. No caverns, active sinks, or sizeable springs were observed, and there are no known mineral resources in the impoundment area. Well data show groundwater levels to be at or above stream level and indicate that the valleys are reasonably tight.

c. Conclusions. Possible adverse geologic features may be thick residuum and weathered rock at the dam abutments and considerable underflow in the stream alluvium. Other than these possibilities, the site appears favorable.

31. BENTON CREEK RESERVOIR (I-41)

a. Site. Located on Benton Creek about 4 miles west of Wesco, the valley is rough, with steep, forested slopes containing numerous rock outcrops. A perennial spring-fed flow courses over a moderately graveled streambed.

b. Geology. Bedrock underlying the damsite is the cherty dolomite of the Gasconade formation. The rock is well jointed, occurs in medium beds, and the upper slopes are somewhat weathered and covered by residual cherty soils. The underlying Eminence dolomite forms the bedrock surface under much of the reservoir's lower slopes. Several springs are located upstream of the damsite, the largest being at or just above flood control pool elevation. No caverns were observed at the site but the surrounding area contains quite a few, and, in both rock formations, cave development is a common feature. Surface iron and clay deposits have been formerly mined in the region, but no active mining or extensive deposits are known at the proposed project. A sand and gravel company has recently begun operations several miles below the damsite.

c. Conclusions. There is no known geological defect at this site. Future studies may show abnormal depth to firm rock on abutments, groundwater-enlarged joints, and other possible leakage conditions.

32. SUMMARY OF TRIBUTARY RESERVOIRS

In the foregoing outline presentation of the "I" sites, it is inferred that all sites will require a normal grout curtain program and seepage control measures across the graveled streambeds. Mineral resources are fully discussed in APPENDIX J. Availability of construction materials in relation to all sites is discussed in later paragraphs of this appendix. Except where noted, foundation rocks are considered to be sufficiently strong to adequately support the structures proposed. Depth of rock weathering and thickness of overburden are considered to be erratic but not excessive unless so stated. Rocks underlying the reservoirs are essentially horizontally bedded.

SECTION VI - GEOLOGIC SUMMARY OF HEADWATER RESERVOIRS

33. DISCUSSION

As explained in SECTION VII, MAIN REPORT, 24 headwater impoundment sites of the 253 studied in 1945 and 1949 by the Missouri Division of Resources and Development were retained for further study and economic analysis. Twelve of these sites fell within the class of reservoirs normally constructed by the Soil Conservation Service. Consequently, design and preparation of cost estimates for these "H" sites were assigned to this agency. The results of site investigations and geologic investigations and the presentation of the geology of the headwater "H" sites are contained in APPENDIX G.

34. GEOLOGIC SUMMARY

The principal geologic problems reported in the above studies involve water-holding capabilities of the rock foundations and the likelihood of having long hauls for earth fill material on several of the sites. Solutions considered in the design where water-holding capabilities were considered adverse include blanketing of exposed outcrops, non-disturbance of reservoir bottom overburden, and grouting of foundation and abutments. No caves, springs, or faults were reported as occurring near the damsites. The bedding of the sedimentary rocks is reported as being generally tight and essentially horizontal. It is also reported that there is no significant variation in the ability of the rock formations to support an earthen dam.

35. RECOMMENDATIONS

It is recommended that the subsurface conditions existing at the "H" sites be explored in future studies. Based on information included in APPENDIX G and independent field studies of the Corps of Engineers, it is also recommended that contingencies in the cost estimates be revised upward to reflect remedial measures and design features unknown at this time. Foundation aspects and considerations involved in an increase of contingencies include:

a. Unknown quantities of excavation, other than streambed cutoff, and high cost of certain excavation.

b. Depth of weathered rock on the dam abutments.

c. Possible need for grouting solutionized rocks at all dams.

d. Uncertainty of condition of foundations of outlet works.

e. Need for and construction of foundation drains.

f. Unknown degree of revetment protection required or provided for.

SECTION VII - SOILS INVESTIGATIONS

36. PURPOSE

Soils investigations of the main stream and tributary damsites were undertaken to develop practical and constructable embankments at the chosen sites and to obtain the information necessary to assess the costs of such embankments. Entering into such investigations are an evaluation of available borrow material, determination of the embankment stability, and an assessment of the abutment soils' ability to retain the reservoir.

37. PROCEDURE

The soils investigations were initiated with a geologic analysis of the parent rock. This was supplemented by an air photo examination and agricultural soil correlation study of the sites. After the preliminary studies, a field reconnaissance was carried out. The reconnaissance allowed optimum location of available drilling effort and reaffirmed the conceptions of the preliminary studies. Final conclusions and sections were developed after study of the borings.

38. BASIC INFORMATION

The basic and detailed geology used in preliminary soil studies, together with appropriate sources, has been discussed. Particular attention is directed to the paragraph on the relation of native rock to overburden. The agricultural soil classifications were obtained from the Soil Map of Missouri prepared by the University of Missouri Agricultural Experiment Station. An excerpt from this map is presented on PLATE D-3. The correlation of soil class to engineering properties was obtained from the Geology and Soils Manual, Missouri State Highway Commission. A tabulation of index properties is presented on TABLE D-3. The results of the limited boring investigations are presented on PLATES D-6 through D-17, which delineate the location and profile of the borings at each major site. The Meramec and Union sites were drilled out in considerable detail during prior investigations (1949). These borings are presented using the classification system in use at that time. The other sites are shown using the Unified Soil Classification System.

39. MAIN STREAM DAMSITES

a. General. The general valley formations throughout the basin consist of a relatively impervious layer overlying pervious sands and gravels. The layer thicknesses vary in relation to each other and in total thickness. Maximum valley fill was found at the Pine Ford site (±25 feet). The minimum fill was 2 to 4 feet at the Irondale site.

Few terrace deposits are present in these narrow, unglaciated valleys. Upland soils are variable in thickness. Dependable borrow in the quantities required is not available from the uplands adjacent to most dams. Borrow sources are, therefore, practically limited to the alluvial valley soils. Consideration was limited in this study to the use of these valley soils for embankment construction. The boring investigation and field reconnaissance were developed to reveal the proportions of pervious and impervious materials present both upstream and downstream of a proposed site. As a general rule, the section for the dam was developed to reflect the percentages of materials present in these alluvial borrow sources. Stripping of the impervious surface materials (up to 10 to 12 feet thick) for use as impervious core was contemplated. Dragline excavation of the lower pervious soils for the outer shells was to follow the stripping. Intermediate zones were to be incorporated in random areas in the embankment. Borrow areas were delineated and haul distances developed on this basis. The variations of constituents and amounts of valley fill resulted in basic section choices, ranging from narrow inclined impervious core to almost homogeneous. The variation in constituents also resulted in incorporation of random zones to allow greater freedom in construction procedures and borrow pit operations. Sections were zoned to allow modern construction techniques. Transition zones were not developed for this study. The sections, as chosen, are presented on plates entitled "DESIGN DETAILS" in APPENDIX E.

b. Embankment design. Assessment of stability and choice of slopes were accomplished through experience and limited computations. Available literature on dams of similar height and composition was reviewed. The earth and rockfill dam data sheets compiled by Waterways Experiment Station were also consulted. Two sites, Union and Meramec, were previously studied in some detail. These studies were made prior to 1949. Shear strengths were evaluated for the embankment and foundation. Testing was described as slow shear; therefore, presumably, the present "S" test was approximated. However, the test results list significant cohesion. It is therefore concluded that the tests more closely represent the "R" or consolidated-undrained condition. Analyses of the embankments at these sites resulted in factors of safety for the "drawdown" condition in the 1.0 to 1.3 range using the above test results. Those dams studied (Union and Meramec) represent the higher embankments and the deeper cutoff conditions found among the proposed sites. Sections for the remainder of the major sites were developed using the Union-Meramec section and the accumulated experience data as guides. Lack of positive shear strength data for the new sites required incorporation of additional safety in the section. The thickness of pervious shells was increased where equivalent slopes were maintained. Where sufficient pervious

material was lacking, the slopes were flattened. In addition, the heights of the new dams ranged about 20 percent less than those analyzed. All embankments are therefore considered stable.

c. Cutoff trench design. As indicated above, the valley soils are pervious to various degrees. All sites have rock 30 feet or less below ground surface. Positive cutoff was chosen at all sites to achieve control of seepage quantity and pressures. Such cutoff was sized to provide a rock-backfill contact of 25 to 30 percent of total dam height.

d. Abutments. Abutment soils are residual at all sites. Depth of expected upland weathering varies from 0 at Irondale to 25 feet at Pine Ford. Weathering of the dominant rocks (limestone, dolomite, and shale) has produced clay matrix soils, basically impervious. Most of these sites have a relatively short distance from end of dam to rock above pool elevation on the divides. With the relatively impervious nature of the natural soils, no attempt has been made to extend the cutoff beyond the abutment proper.

40. TRIBUTARY DAMSITES

a. General. Studies similar to those performed for the main stream sites were also accomplished for the tributary dams, the major exception being the omission of boring investigations. In general, the "I" sites occur nearer the headwaters of the basin. These areas have less impervious material available. The stream valleys are choked with sands and gravels. The exception to this rule occurs in the northwestern part of the basin near the headwaters of the Bourbeuse River. This area is underlain with soft Pennsylvanian sediments, and the topography is much less rugged. The valleys are wider and contain much more clay.

b. Embankment design. Two sections were established for use in these basically different areas. A pervious section with a thin, inclined, impervious core was chosen for the major portion of the basin. An essentially homogeneous impervious section was chosen for the Bourbeuse River headwater area. A large random zone was incorporated into the sections to allow for local variations in the materials available at each site. Slopes were chosen based on the experience, surveys, and limited analyses performed for the main dams. Cutoffs were provided to control seepage.

41. DAMSITES FOR PUMPED STORAGE IMPOUNDMENTS

The pumped storage power dams at the Meramec, Salem, and Pine Ford sites were studied, using data developed for the adjacent

main dams. These data, plus experience, site examinations, and geologic and soil surveys, were combined to yield borrow sources, cutoff requirements, slopes, and embankment sections.

42. HEADWATER DAMSITES

The investigation and design of the dams for headwater sites were developed by the Soil Conservation Service, Department of Agriculture, and are reported in APPENDIX G.

SECTION VIII - AVAILABILITY OF CONSTRUCTION MATERIALS

43. GENERAL

High-quality crushed stone sources are noticeably absent in the Meramec Basin, although much of the basin is underlain by massive lower Ordovician and upper Cambrian dolomites which are believed to be of acceptable quality. See PLATE D-1. This lack of commercial stone sources can be attributed to the reliance of the local construction industry upon the readily available and inexpensive river gravels.

44. COMMERCIAL SOURCES OF MATERIALS

a. Stone. The small producers of crushed stone present near the northern and western basin boundaries work strata belonging to the lower Ordovician Beekmantown group or the Roubidoux formation, geologic units which are very heterogeneous and which are believed unsuitable as sources of materials. Large-volume producers of high-quality crushed stone products are present only beyond the northeastern basin boundary, in or near the greater St. Louis area, and near or beyond the eastern edge of the basin. Newly opened mines in the central Meramec Basin were also considered as potential stone sources. Initial investigations reveal, however, that the quantity of waste rock will steadily diminish as the ore bodies are developed and that the mining companies anticipate using their waste materials for their own construction.

b. Sand and gravel. Most of the Meramec Basin streams contain workable deposits of sand and gravel. The equipment used by the operating sources varies from the simple excavational and truck loading facilities of the rural bank-run sand and gravel producers to the extensive dredging, washing, screening, and crushing facilities of producers near large metropolitan areas. Sand producers which dredge the Missouri River are within economical distance of some of the northern basin damsites. Mississippi River sand does not appear to be economically competitive, even for the easternmost damsites.

45. UNDEVELOPED SOURCES OF MATERIALS

a. Stone. Because of the lack of acceptable crushed stone sources within economical distance of the northwestern and western sites, it is anticipated that previously undeveloped sources of materials will be opened. For the major damsites, the quality of the bedrock and the quantity of rock excavation will permit on-site processing of excavated materials. It is also anticipated that a centrally located on-site quarry may be opened to supply the western basin intermediate sites for which the processing of excavated materials is economically impractical. An off-site potential quarry location,

centrally situated with respect to the northwestern damsites, has been located by map reconnaissance. Additional investigations will be required in order to determine the quality and quantity of stone at this site.

b. Sand and gravel. As has been previously stated, sand and gravel deposits are present in all the streams for which dams are planned. During a more detailed phase of investigation, a reconnaissance in the vicinity of each project site will be required in order to locate and evaluate these sand and gravel deposits.

46. DISCUSSION

a. Materials from sources working the lower Ordovician Beekmantown group or the Roubidoux formation are not believed to be of acceptable quality.

b. Large sources which produce crushed stone of acceptable quality are within economical distance of only the northeastern and eastern damsites.

c. At the major damsites, extensive use of excavated materials is anticipated.

d. In order to supply the western and northwestern intermediate project sites, it will be most economical to open previously undeveloped on-site or off-site quarries.

e. Local gravels will not be acceptable as coarse aggregate in exposed concrete due to a lack of sizes large enough for mass concrete and due to poor performance in previous freeze-thaw tests.

f. During a more detailed phase of investigation, undeveloped sand and gravel deposits near proposed damsites will be located and tested to evaluate their potential as sources of construction materials.

TABLE D-1
Measured springs in Meramec Basin

	Name	Average flow (sec. ft.)	Geological formation
1.	Meramec	150.0	Gasconade
2.	Westover	10.0	Gasconade
3.	Kratz	8.0	Gasconade
4.	Howes Mill	7.5	Eminence
5.	Blue (Crawford Co.)	5.0	Gasconade
6.	Roaring (Crawford Co.)	4.1	Gasconade
7.	Evans	2.5	Gasconade
8.	Racing	2.3	Gasconade
9.	James	2.2	Eminence
10.	Cold	2.0	Gasconade
11.	Hopewell	2.0	Eminence
12.	Woodlock	2.0	Eminence
13.	Roaring (Franklin Co.)	1.7	Gasconade
14.	Collins	1.6	Gasconade
15.	Onondaga	1.5	Eminence
16.	Steelville	1.5	Gasconade
17.	Elm (Franklin Co.)	1.2	Eminence
18.	McIntosh	1.2	Gasconade
19.	Richart	1.2	Gasconade
20.	Beaver	(less than 1 S.F.)	Gasconade
21.	Blue Grass	(less than 1 S.F.)	Plattin
22.	Brook	(less than 1 S.F.)	Gasconade
23.	Brown	(less than 1 S.F.)	Gasconade
24.	Elm (Crawford Co.)	(less than 1 S.F.)	Gasconade
25.	Falling	(less than 1 S.F.)	Eminence
26.	Indian	(less than 1 S.F.)	Gasconade
27.	Lake	(less than 1 S.F.)	Gasconade
28.	McDade	(less than 1 S.F.)	Roubidoux
29.	Mint	(less than 1 S.F.)	Eminence
30.	Rock	(less than 1 S.F.)	Jefferson City
31.	Rott Road	(less than 1 S.F.)	Salem

TABLE D-2
Caverns in Meramec Basin

Name	County location	Geologic formation
Bat	Crawford	Eminence
Bear	Crawford	Eminence
Cathedral	Crawford	Eminence
Fault	Crawford	Eminence
Onondaga*	Crawford	Eminence
Puckett	Crawford	Gasconade
Bat	Franklin	Eminence
Bear	Franklin	Eminence
Campbell Hollow	Franklin	Eminence
Eddy	Franklin	Eminence
Fisher*	Franklin	Eminence
Greene	Franklin	Eminence
Indian	Franklin	Eminence
Meramec*	Franklin	Eminence
Mud	Franklin	Eminence
Mushroom	Franklin	Eminence
River	Franklin	Eminence
Sheep	Franklin	Eminence
Walker	Franklin	Eminence
Guthoerl	Dent	Eminence
Indian Hill	Dent	Gasconade
Money	Dent	Eminence
Salt Peter	Dent	Eminence
Short Bend	Dent	Eminence
Watson	Dent	Eminence
Marcellus	Phelps	Gasconade
St. James Tunnel	Phelps	Gasconade
Shelton	Phelps	Gasconade
Lenox	Phelps	Gasconade
Rankin	St. Louis	Plattin
Green	Washington	Eminence
Hamilton	Washington	Eminence

*Commercialized

TABLE D-3
Soils of the Meramec Basin

Soil Series | **Typical Profile**

CLARKSVILLE STONY LOAM

Area - Ozark Upland
Geological Formation - Gasconade & Eminence
Subsoil Texture - Stony silty clay loam
Topography - Very hilly (more than Clarksville gravelly loam)
Soil Forming Material - Cherty and dolomitic limestone

SALEM

Boring SA-4

This is a stony silty clay loam, with fairly large angular rock fragments, that is so similar to the Clarksville gravelly that it is difficult to differentiate between them. Horizon "A" is lost during removal of vegetation, and is of little value for discussion. Horizon "B's" texture becomes heavier with increasing depth. Horizon "C" is stiff and often contains large amounts of iron; usually it will contain fewer rock fragments than "A" and "B" but occasionally the high chert content is found throughout the soil section. Horizon "C" ranges from a non-plastic to a very highly plastic soil. The material has a high volume change. The mixture of clay and stone fragments with the correct moisture added makes good fill material. In situ permeability is moderately high due to the high chert content.

CLARKSVILLE GRAVELLY LOAM

Area - Ozark Upland
Geological Formation - Bonne Terre (Rhyolite) Potosi
Subsoil Texture - Gravelly Silty Clay Loam
Topography - Hilly; greater than 14% slope
Soil Forming Material - Cherty & Dolomitic Limestone Residual

PINE FORD

Boring PF-10

Closely related to Clarksville Stony (above) with difference being mainly in lower chert content and a less rugged topography. Often contains pockets of rock free, highly plastic red clay CH. In situ permeability is moderately high.

1

2

TABLE D-3
oils of the Meramec Basin

Typical Profile

SALEM

Boring SA-4

HORIZON	A	B	C
Liquid Limit	19-35	18-45	22-75
Plastic Index	0-18	0-27	1-45
Group Index	0-11	0-16	0-20
Silt & Clay %	21-84	14-93	14-92
Optimum Moisture	6-17%	7-20%	9-32%
Maximum Density	102-131	102-130	78-127
Stone Content	20-50%	20-50%	Less than "A"

loam)

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volume
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high

PINE FORD

Boring PF-10

HORIZON	A	B	C
Liquid Limit	14-37	12-61	25-85
Plastic Index	0-13	0-39	9-54
Group Index	0-9	0-16	0-20
Silt & Clay %	27-90	19-90	0-93
Optimum Moisture	9-18%	8-21%	8-32%
Maximum Density	99-124	103-131	78-127
Chert Content	Up to 50%	More than 50%	Up to 90%

idual

ing
on-

HUNTINGTON LOAM

SALEM

Boring SA-7

Area - Ozark Stream Valleys & Flood Plains
Topography - Nearly Level
Soil Forming Material - Outwash Alluvium from Ozark Upland
Subsoil Texture - Silt Loam

The Huntington silt loam occupies the Ozark Stream Valleys; it varies in gravel type and content according to upland soils of the area.

The gravel content is higher where Clarksville soils are the parent material.

The gravelly loam provides excellent embankment or select capping material over poorer soils.

The silty type may be difficult to compact, but is seldom encountered in construction. It will show instability if used in construction work at moisture content near or above optimum.

In situ permeability is moderately free.

UNION SILT LOAM

PINE FORD

Boring PF-3

Area - Eastern Ozark Upland Border
Geological Formation - Gasconade
Subsoil Texture - Silty Clay
Topography - Hilly; greater than 14% slope
Soil Forming Material - Residual Dolomitic Limestone & Loess

The Union is a silt loam that is questionable in derivation, but is generally accepted as consisting of loessial material in the upper portion and residual from underlying rock formation in the lower portions. "A" horizon is usually a stone free, floury silt that has a varying thickness; "B" and "C" horizons are silty clay loams with the latter having concretionary material so abundant that a hard-pan character is imparted. Below the hard-pan residual chert in varying amounts is scattered throughout the soil. In situ permeability is moderate.

In situ or when placed in fills, the Union silt loam is very susceptible to destructive erosion.

2

TABLE D-3 (Cont'd)

SALEM

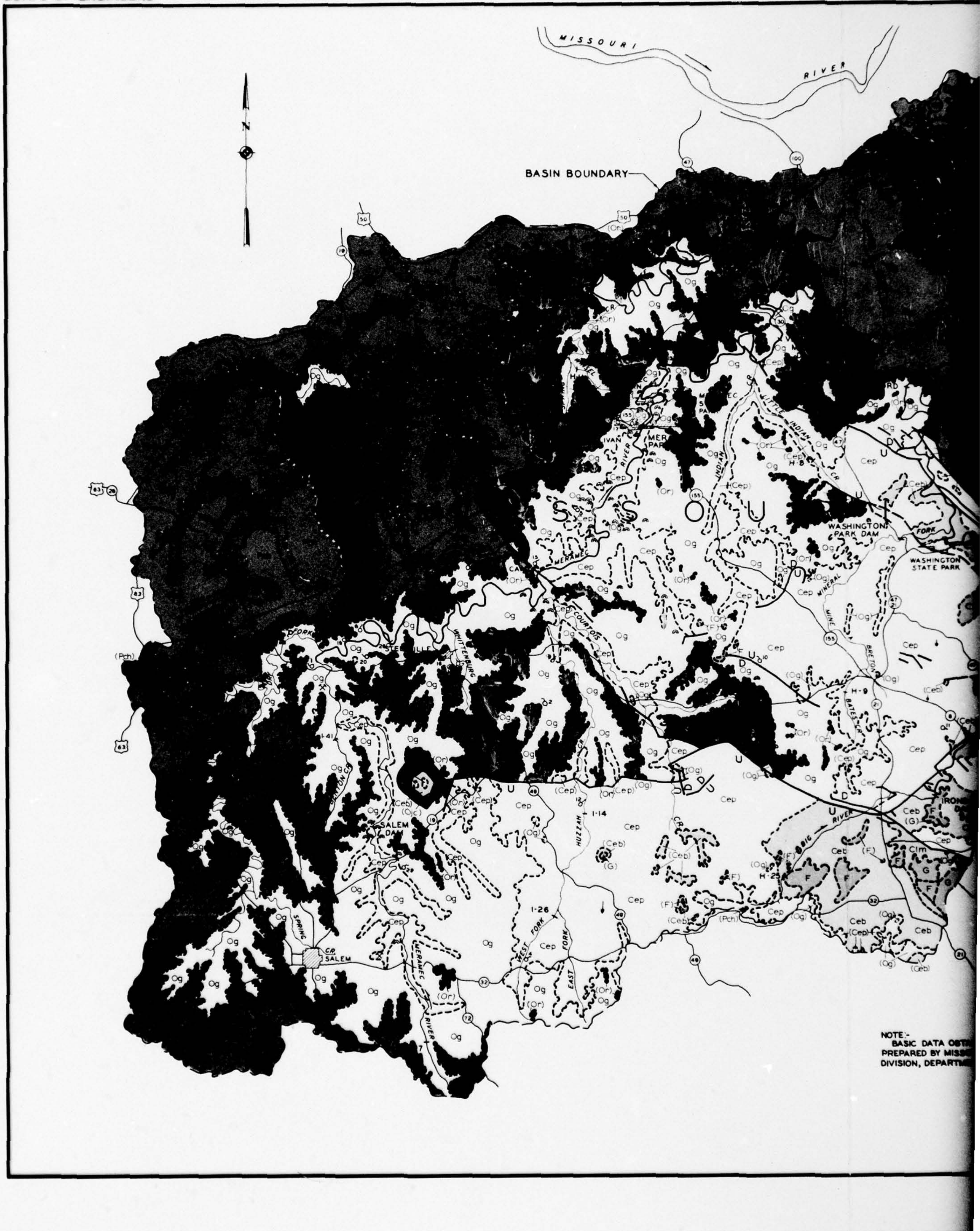
Boring SA-7

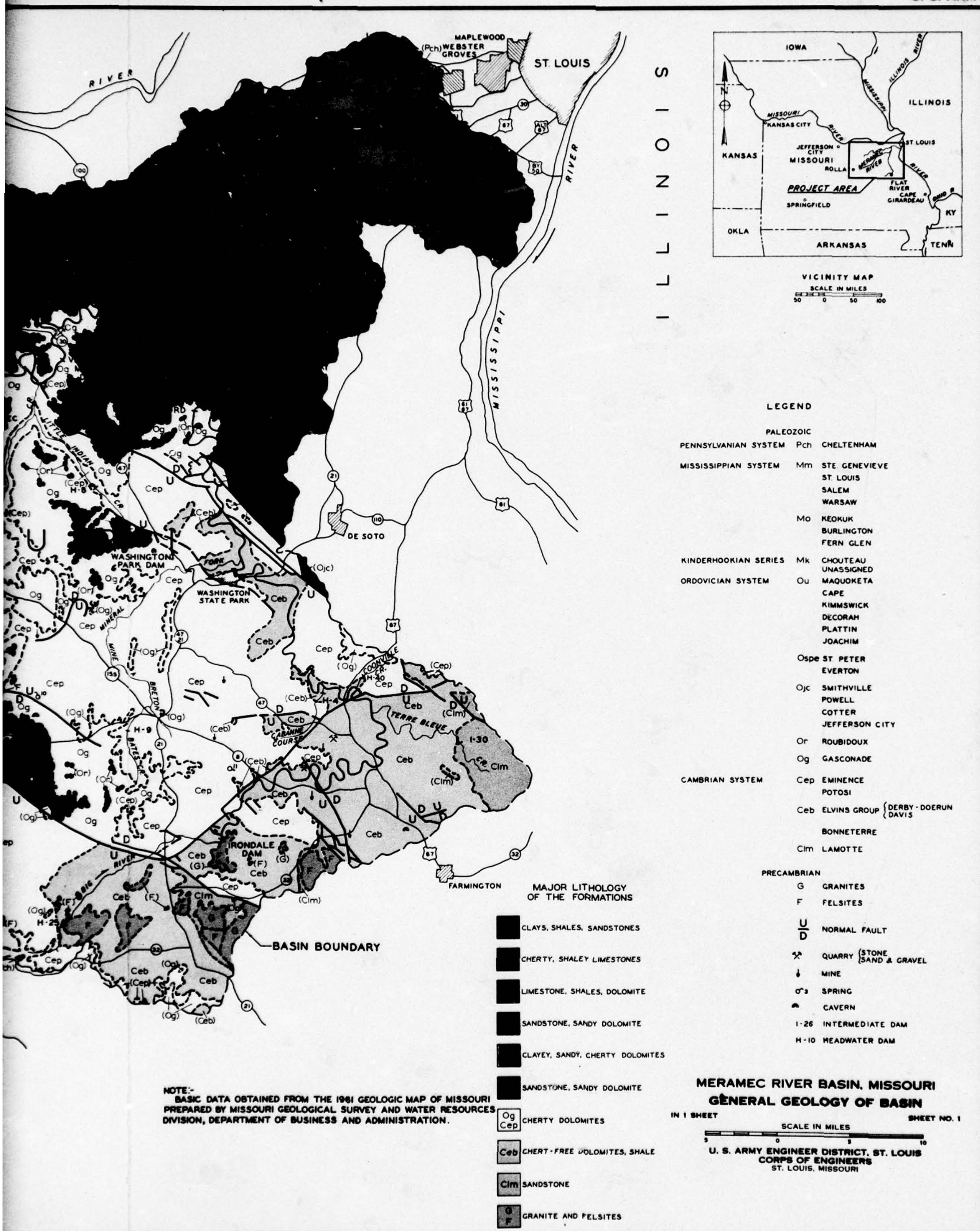
HORIZON	A	B	C
Liquid Limit	26-28	26-30	27
Plastic Index	6-7	9-12	9
Group Index	4-6	4-7	3
Silt & Clay	52-70	44-67	44
Optimum Moisture	14-15%	13-15%	13%
Maximum Density	110-115	112-118	119

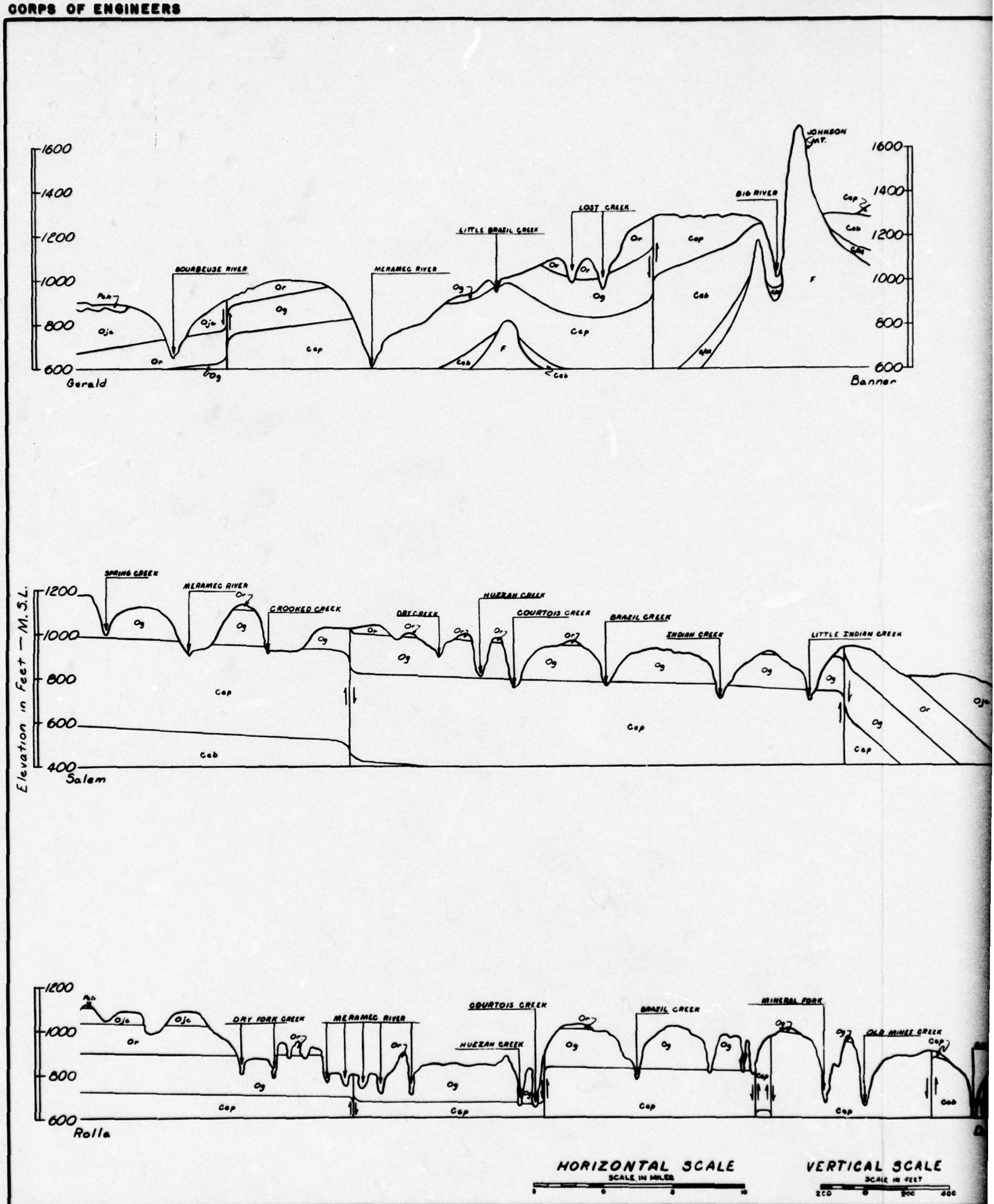
PINE FORD

Boring PF-3

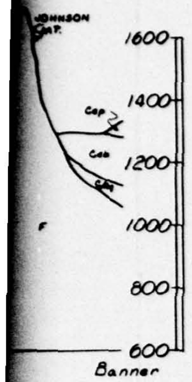
HORIZON	A	B	C
Liquid Limit	30	39	47
Plastic Index	7	20	28
Group Index	9	12	14
Silt & Clay	86	90	79
Optimum Moisture	17%	19%	19%
Maximum Density	105	105	103

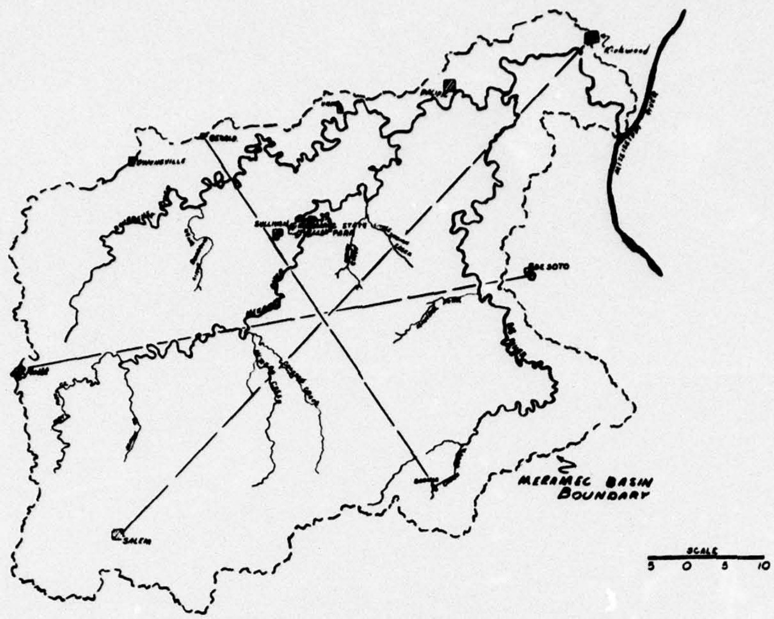

MISSOURI
RIVER
N
BASIN BOUNDARY
WASHINGTON PARK DAM
WASHINGTON STATE PARK
SALEM DAM
SALEM
MERAMEC
HUZZAH
BIG RIVER
NOTE:-
BASIC DATA OBT
PREPARED BY MISS
DIVISION, DEPART


MAPLEWOOD
WEBSTER GROVES
ST LOUIS
ILLINOIS
MISSISSIPPI RIVER
DE SOTO
WASHINGTON PARK DAM
WASHINGTON STATE PARK
TERRE BLEUE
IRONDALE DAM
BASIN BOUNDARY
FARMINGTON
VICINITY MAP
SCALE IN MILES
IOWA
ILLINOIS
KANSAS
MISSOURI
KANSAS CITY
JEFFERSON CITY
ROLLA
PROJECT AREA
SPRINGFIELD
FLAT RIVER
CAPE GIRARDEAU
OKLA
ARKANSAS
KY
TENN
LEGEND
PALEOZOIC
PENNSYLVANIAN SYSTEM Pch CHELTENHAM
MISSISSIPPIAN SYSTEM Mm STE GENEVIEVE, ST LOUIS, SALEM, WARSAW
Mo KEOKUK, BURLINGTON, FERN GLEN
KINDERHOOKIAN SERIES Mk CHOUTEAU UNASSIGNED
ORDOVICIAN SYSTEM Ou MAQUOKETA, CAPE, KIMMSWICK, DECORAH, PLATTIN, JOACHIM
Ospe ST PETER, EVERTON
Ojc SMITHVILLE, POWELL, COTTER, JEFFERSON CITY
Or ROUBIDOUX
Og GASCONADE
CAMBRIAN SYSTEM Cep EMINENCE, POTOSI
Ceb ELVINS GROUP {DERBY-DOERUN, DAVIS}, BONNETERRE
Clm LAMOTTE
PRECAMBRIAN
G GRANITES
F FELSITES
U/D NORMAL FAULT
QUARRY {STONE, SAND & GRAVEL}
MINE
SPRING
CAVERN
I-26 INTERMEDIATE DAM
H-10 HEADWATER DAM
MAJOR LITHOLOGY OF THE FORMATIONS
CLAYS, SHALES, SANDSTONES
CHERTY, SHALEY LIMESTONES
LIMESTONE, SHALES, DOLOMITE
SANDSTONE, SANDY DOLOMITE
CLAYEY, SANDY, CHERTY DOLOMITES
SANDSTONE, SANDY DOLOMITE
Og Cep CHERTY DOLOMITES
Ceb CHERT-FREE DOLOMITES, SHALE
Clm SANDSTONE
G F GRANITE AND FELSITES
NOTE:- BASIC DATA OBTAINED FROM THE 1961 GEOLOGIC MAP OF MISSOURI PREPARED BY MISSOURI GEOLOGICAL SURVEY AND WATER RESOURCES DIVISION, DEPARTMENT OF BUSINESS AND ADMINISTRATION.
MERAMEC RIVER BASIN, MISSOURI
GENERAL GEOLOGY OF BASIN
IN 1 SHEET
SHEET NO. 1
SCALE IN MILES
U. S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

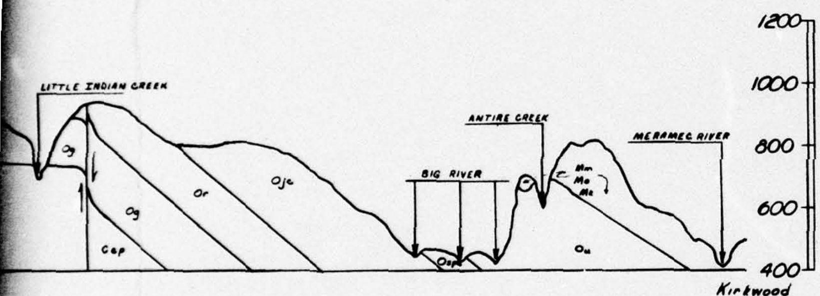


JOHNSON MT.
BIG RIVER
LOST CREEK
LITTLE BRAZIL CREEK
BOURBEUSE RIVER
MERAMEC RIVER
Gerald
Banner
SPRING CREEK
MERAMEC RIVER
CROOKED CREEK
DRY CREEK
HUZZAH CREEK
COURTOIS CREEK
BRAZIL CREEK
INDIAN CREEK
LITTLE INDIAN CREEK
Elevation in Feet — M. S. L.
Salem
DRY FORK CREEK
MERAMEC RIVER
COURTOIS CREEK
HUZZAH CREEK
BRAZIL CREEK
MINERAL FORK
OLD MINES CREEK
Rolla
HORIZONTAL SCALE
SCALE IN MILES
VERTICAL SCALE
SCALE IN FEET

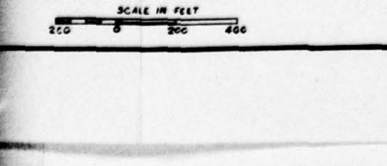




VICINITY MAP



NOTE: The vertical exaggeration inherent in these sections preclude accurate delineation of structure. The sections are presented to show the general attitude of the rocks and their surface expression.



VERTICAL SCALE

SCALE IN FEET

250 0 200 400

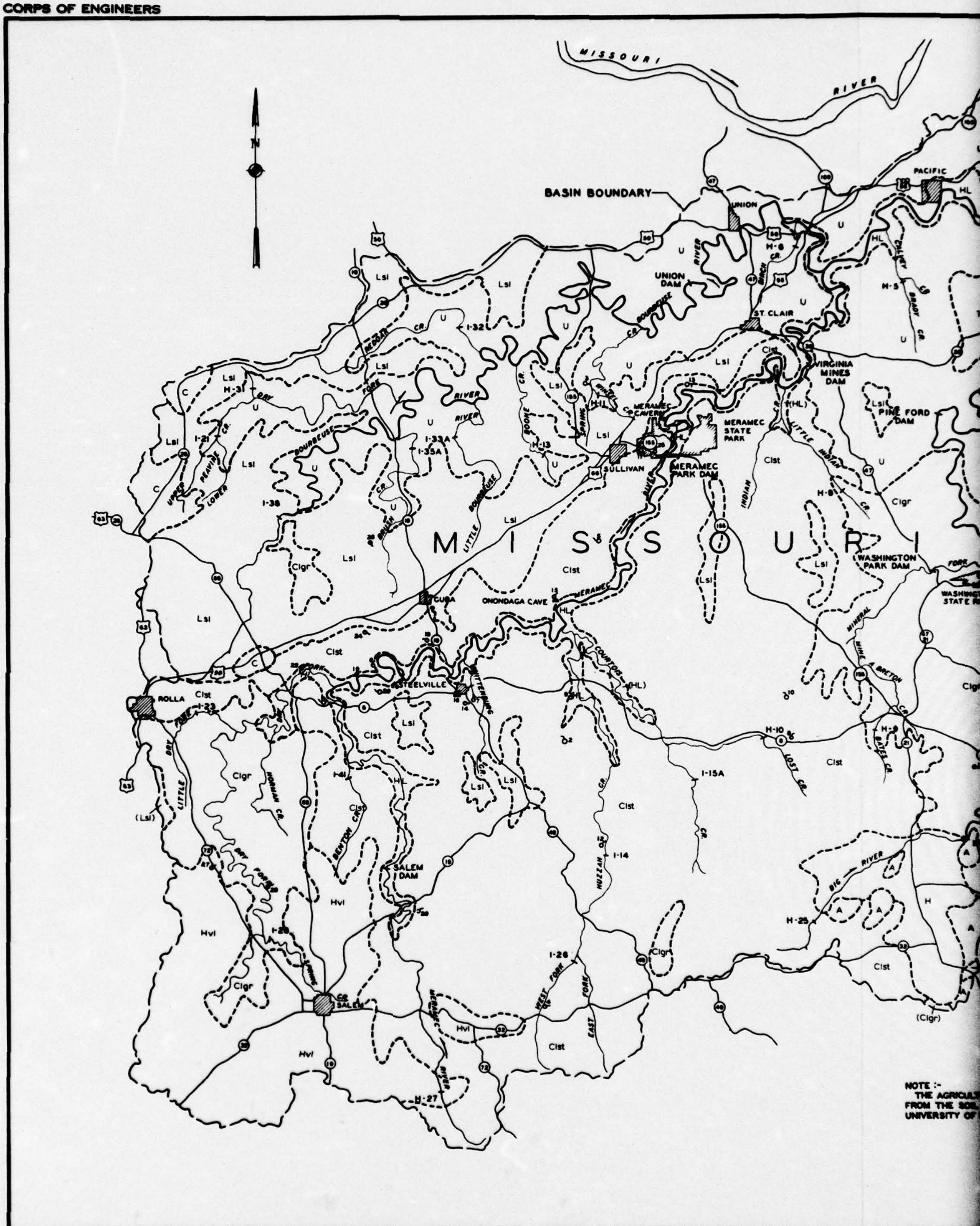
MERAMEC RIVER BASIN, MISSOURI
GEOLOGIC CROSS SECTIONS

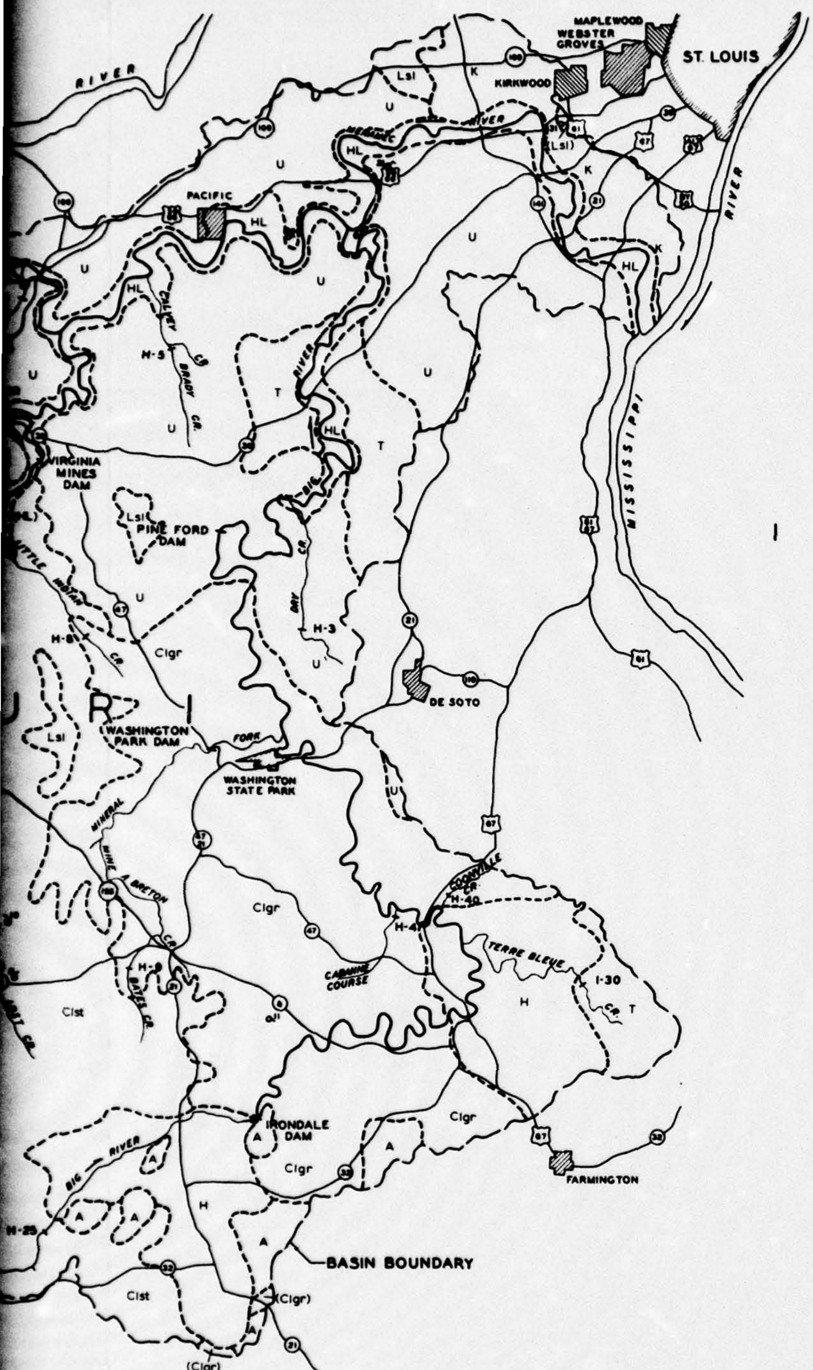
IN 1 SHEET — SHEET NO. 1

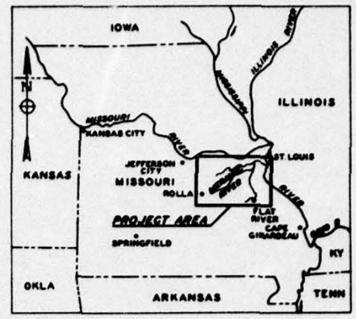
SCALE AS SHOWN

U. S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

CORPS OF ENGINEERS







VICINITY MAP

SCALE IN MILES

LEGEND

K	KNOX SILT LOAM
C	CHEROKEE SILT LOAM
Lsl	LEBANON SILT LOAM
U	UNION SILT LOAM
H	HAGERSTOWN SILT LOAM
Clgr	CLARKSVILLE GRAVELLY LOAM
Clst	CLARKSVILLE STONY LOAM
T	TILSIT LOAM
Hvl	HANCEVILLE LOAM
A	ASHE STONY LOAM
HL	HUNTINGTON LOAM
ᑫ	SPRING
I-26	INTERMEDIATE DAM
H-10	HEADWATER DAM

NOTE :-
THE AGRICULTURAL SOIL CLASSIFICATIONS WERE OBTAINED FROM THE SOIL MAP OF MISSOURI PREPARED BY THE UNIVERSITY OF MISSOURI AGRICULTURAL EXPERIMENT STATION.

MERAMEC RIVER BASIN, MISSOURI
AGRICULTURAL SOIL CLASSIFICATION

IN 1 SHEET — SHEET NO. 1

SCALE IN MILES

U. S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

UNIFIED SOIL CLASSIFICATION

MAJOR DIVISION		TYPE	LETTER SYMBOL	SYMBOL	TYPICAL NAMES
COARSE - GRAINED SOILS More than half of material is larger than No 200 sieve size	GRAVELS More than half of coarse fraction is larger than No 4 sieve size	CLEAN GRAVEL (Little or No Fines)	GW		GRAVEL, Well Graded, gravel-sand mixtures, little or no fines
			GP		GRAVEL, Poorly Graded, gravel-sand mixtures, little or no fines
		GRAVEL WITH FINES (Appreciable Amount of Fines)	GM		SILTY GRAVEL, gravel-sand-silt mixtures
			GC		CLAYEY GRAVEL, gravel-sand-clay mixtures
	SANDS More than half of coarse fraction is smaller than No 4 sieve size	CLEAN SAND (Little or No Fines)	SW		SAND, Well-Graded, gravelly sands
			SP		SAND, Poorly-Graded, gravelly sands
		SANDS WITH FINES (Appreciable Amount of Fines)	SM		SILTY SAND, sand-silt mixtures
			SC		CLAYEY SAND, sand-clay mixtures
FINE - GRAINED SOILS More than half the material is smaller than No. 200 sieve size		SILTS AND CLAYS (Liquid Limit < 50)	ML		SILT & very fine sand, silty or clayey fine sand or clayey silt with slight plasticity
			CL		LEAN CLAY; Sandy Clay; Silty Clay; of low to medium plasticity
			OL		ORGANIC SILTS and organic silty clays of low plasticity
		SILTS AND CLAYS (Liquid Limit > 50)	MH		SILT, fine sandy or silty soil with high plasticity
			CH		FAT CLAY, inorganic clay of high plasticity
			OH		ORGANIC CLAYS of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS			Pt		PEAT, and other highly organic soil
WOOD			Wd		WOOD
SHELLS			Sl		SHELLS
NO SAMPLE					
					Ⓐ — CLASSIFICATION DETERMINED BY PROCESS OF DRILLING.

NOTE: Soils possessing characteristics of two groups are designated by combinations of group symbols

NOTES:
FIGURES TO LEFT
Are natural water content
When underlined denotes
FIGURES TO LEFT
Are liquid and plastic lim
SYMBOLS TO LEFT
∇ Ground-water surf
Ⓒ Denotes location of
Ⓢ Denotes location of
Ⓡ Denotes location of
Ⓞ Denotes location of
Ⓣ Denotes location of of the above three
FW Denotes free water
FIGURES TO RIGHT
Are values of cohesion in
In parenthesis are drivin standard split spoon sa with a 30" drop
Where underlined with a per second of undisturbe
Where underlined with a per second of sample re

* The D_{10} size of a soil is th is finer, and 90% coarser th

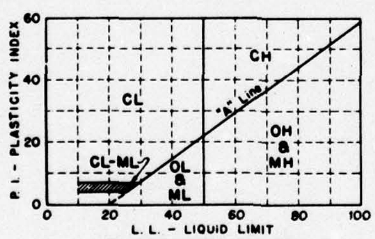
** Results of these tests are Office, if these symbols appe

DESCRIPTIVE SYMBOLS

COLOR	SYMBOL
TAN	T
YELLOW	Y
RED	R
BLACK	BK
GRAY	Gr
LIGHT GRAY	lGr
DARK GRAY	dGr
BROWN	Br
LIGHT BROWN	lBr
DARK BROWN	dBr
BROWNISH-GRAY	br Gr
GRAYISH-BROWN	gy Br
GREENISH-GRAY	gn Gr
GRAYISH-GREEN	gy Gn
GREEN	Gn
BLUE	Bl
BLUE-GREEN	Bl Gn
WHITE	Wh
MOTTLED	Mot

CONSISTENCY FOR COHESIVE SOILS

CONSISTENCY	COHESION IN LBS./SQ.FT. FROM UNCONFINED COMPRESSION TEST	SYMBOL
VERY SOFT	< 250	vSo
SOFT	250 - 500	So
MEDIUM	500 - 1000	M
STIFF	1000 - 2000	St
VERY STIFF	2000 - 4000	vSt
HARD	> 4000	H



PLASTICITY CHART

For classification of fine - grained soils

MODIFICATIONS

MODIFICATION	SYMBOL
Traces	Tr-
Fine	F
Medium	M
Coarse	C
Concretions	cc
Rootlets	rt
Lignite fragments	lg
Shale fragments	sh
Sandstone fragments	sds
Shell fragments	slf
Organic matter	O
Clay strata or lenses	CS
Silt strata or lenses	SIS
Sand strata or lenses	SS
Sandy	S
Gravelly	G
Boulders	B
Slickensides	SL
Wood	Wd
Oxidized	Ox

GENERAL NOTES:

While the borings are repre and for their respective vertical surface materials of the region be considered as differing mate

Ground-water elevations sho ed on the dates shown. Absence ground-water data is availab encountered at the locations ar

Consistency of cohesive soil examination and is approxim shear strengths from unconfi

2

NOTES:
FIGURES TO LEFT OF BORING UNDER COLUMN "W OR D_{10}"
Are natural water contents in percent dry weight
When underlined denotes D_{10} size in mm *
FIGURES TO LEFT OF BORING UNDER COLUMNS "LL" AND "PL"
Are liquid and plastic limits, respectively
SYMBOLS TO LEFT OF BORING
▽ Ground-water surface and date observed
C Denotes location of consolidation test **
S Denotes location of consolidated-drained direct shear test **
R Denotes location of consolidated-undrained triaxial compression test **
Q Denotes location of unconsolidated-undrained triaxial compression test **
T Denotes location of sample subjected to consolidation test and each of the above three types of shear tests **
FW Denotes free water
FIGURES TO RIGHT OF BORING
Are values of cohesion in lbs./sq.ft. from unconfined compression tests
In parenthesis are driving resistances in blows per foot determined with a standard split spoon sampler ($1\frac{3}{8}$" I.D., 2" O.D.) and a 140 lb. driving hammer with a 30" drop
Where underlined with a solid line denotes laboratory permeability in centimeters per second of undisturbed sample
Where underlined with a dashed line denotes laboratory permeability in centimeters per second of sample remoulded to the estimated natural void ratio

* The D_{10} size of a soil is the grain diameter in millimeters of which 10% of the soil is finer, and 90% coarser than size D_{10}.

**Results of these tests are available for inspection in the U.S. Army Engineer District Office, if these symbols appear beside the boring logs on the drawings.

GENERAL NOTES:

While the borings are representative of subsurface conditions at their respective locations and for their respective vertical reaches, local minor variations in characteristics of the subsurface materials of the region are anticipated and, if encountered, such variations will not be considered as differing materially within the purview of clause 4 of the contract.

Ground-water elevations shown on the boring logs represent ground-water surfaces encountered on the dates shown. Absence of water surface data on certain borings implies that no ground-water data is available, but does not necessarily mean that ground water will not be encountered at the locations or within the vertical reaches of these borings.

Consistency of cohesive soils shown on the boring logs is based on driller's log and visual examination and is approximate, except within those vertical reaches of the borings where shear strengths from unconfined compression tests are shown.

MERAMEC RIVER BASIN, MISSOURI
SOIL BORING LEGEND

IN 1 SHEET — SHEET NO. 1

SCALE AS SHOWN

U. S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

CLASSIFICATION AND DESCRIPTION OF ROCKS

GROUP	SYMBOL	ROCK CLASSIFICATION	GROUP	SYMBOL	ROCK CLASSIFICATION
SEDIMENTARY ROCKS		CONGLOMERATE	METAMORPHIC ROCKS		GNEISS
		SANDSTONE			SCHIST
		GRAYWACKE			QUARTZITE
		SILTSTONE			MARBLE
		INDURATED CLAY OR CLAYSTONE			SOAPSTONE AND SERPENTINE
		COMPACTION SHALE			SLATE
		CEMENTED SHALE			
		COAL			
		LIMESTONE			
		DOLOMITE			
		CHALK (OR MARL)	IGNEOUS ROCKS		GRANITE
					DIORITE
					GABBRO
					RHYOLITE
					ANDESITE
					BASALT (TRAP)
					TUFF OR TUFF BRECCIA
					AGGLOMERATE FLOW BRECCIA

KEY TO PHYSICAL PROPERTIES OF ROCK

Bedding Characteristics —
1. Massive
2. Thin to medium bedded
3. Fissile
4. Cross—bedded
5. Foliated
6. Platy
7. Fragmental

Lithologic Characteristics —
8. Clayey
9. Shaly
10. Calcareous (limy)
11. Siliceous
12. Sandy
13. Silty
14. Plastic seams
15. Carbonaceous
16. Fossiliferous
17. Ferruginous

Hardness and Degree of Cementation —
18. Very soft or plastic
19. Soft—Can be scratched with fingernail
20. Moderately hard—Can be scratched easily with knife; cannot be scratched with fingernail
21. Hard—Difficult to scratch with knife
22. Very hard—Cannot be scratched with
23. Poorly cemented
24. Cemented

Texture —
25. Dense
26. Fine
27. Medium
28. Coarse

Structure —
29. Bedding
   a. Flat
   b. Gently dipping
   c. Steeply dipping
30. Fractures, scattered
31. Fractures, closely spaced
32. Brecciated (sheared & fragmented)
33. Joints
34. Faulted
35. Slickensides

Degree of Weathering —
36. Unweathered
37. Slightly weathered
38. Badly weathered

Solution and Void Conditions —
39. Solid, contains no voids
40. Vuggy (pitted)
41. Vesicular
42. Porous
43. Cavities
44. Cavernous

Swelling Properties —
45. Non—swelling
46. Swelling

Slaking Properties —
47. Non—slaking
48. Slakes slowly on exposure
49. Slakes readily on exposure

PHYSICAL PROPERTIES OF ROCKS

1. Massive
2. Thin to medium bedded
3. Fissile
4. Cross—bedded
5. Foliated
6. Platy
7. Fragmental

8. Clayey
9. Shaly
10. Calcareous (limy)
11. Siliceous
12. Sandy
13. Silty
14. Plastic seams
15. Carbonaceous
16. Fossiliferous
17. Ferruginous

18. Very soft or plastic
19. Soft—Can be scratched with fingernail
20. Moderately hard—Can be scratched easily with knife; cannot be scratched with fingernail
21. Hard—Difficult to scratch with knife
22. Very hard—Cannot be scratched with knife
23. Poorly cemented
24. Cemented

25. Dense
26. Fine
27. Medium
28. Coarse

29. Bedding
   a. Flat
   b. Gently dipping
   c. Steeply dipping
30. Fractures, scattered
31. Fractures, closely spaced
32. Brecciated (sheared & fragmented)

(30–32: a. Open; b. Cemented or tight)

33. Joints
34. Faulted
35. Slickensides

36. Unweathered
37. Slightly weathered
38. Badly weathered

39. Solid, contains no voids
40. Vuggy (pitted)
41. Vesicular
42. Porous
43. Cavities
44. Cavernous

45. Non—swelling
46. Swelling

47. Non—slaking
48. Slakes slowly on exposure
49. Slakes readily on exposure

NOTE:

WHILE THE BORINGS ARE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT THEIR RESPECTIVE LOCATIONS AND FOR THEIR RESPECTIVE VERTICAL REACHES, LOCAL MINOR VARIATIONS IN CHARACTERISTICS OF THE SUBSURFACE MATERIALS OF THE REGION ARE ANTICIPATED AND, IF ENCOUNTERED, SUCH VARIATIONS WILL NOT BE CONSIDERED AS DIFFERING MATERIALLY WITHIN THE PURVIEW OF CLAUSE 4 OF THE CONTRACT.

GROUND—WATER ELEVATIONS SHOWN ON BORING LOGS REPRESENT GROUND—WATER SURFACES ENCOUNTERED ON THE DATES SHOWN. ABSENCE OF WATER SURFACE DATA ON CERTAIN BORINGS IMPLIES THAT NO GROUND-WATER DATA IS AVAILABLE, BUT DOES NOT NECESSARILY MEAN THAT GROUND WATER WILL NOT BE ENCOUNTERED AT THE LOCATIONS OR WITHIN THE VERTICAL REACHES OF THESE BORINGS.

(A) CLASSIFICATION DETERMINED BY PROCESS OF DRILLING

5 — 50# PRESSURE TEST RESULTS SHOWN AS 5 GALS./MIN. AT 50 PSI

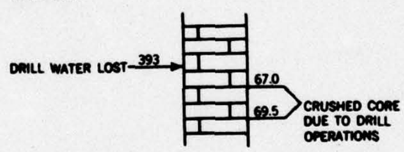
GROUND-WATER SURFACE AND DATE OBSERVED

CORE LOSS OR NO SAMPLE

393 → SPECIAL FEATURE OR DRILLING OPERATION AT A SPECIFIC ELEVATION

67.0 / 69.5 SPECIAL FEATURE VERTICALLY DISTRIBUTED

EXAMPLES:

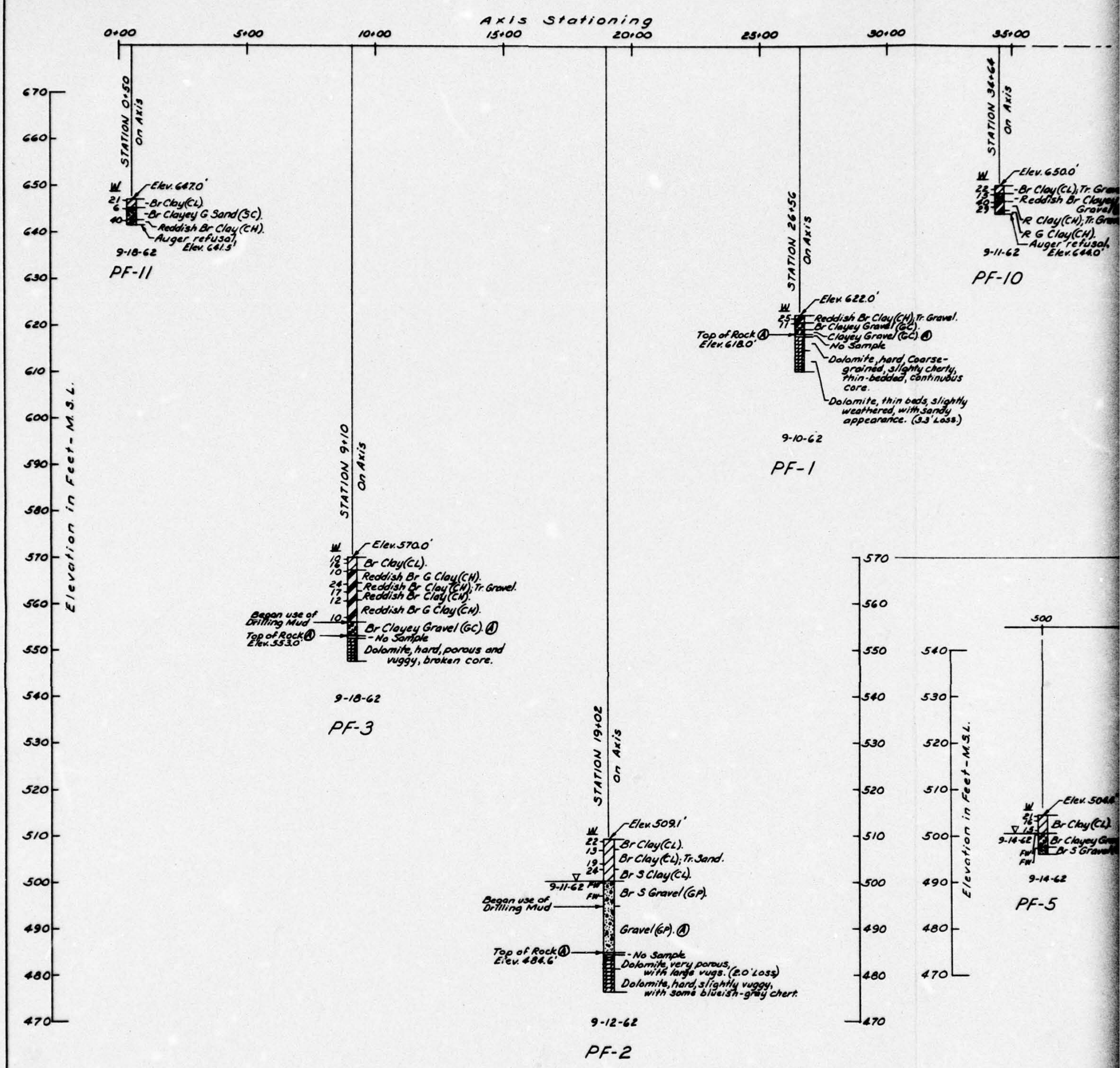


MERAMEC RIVER BASIN, MISSOURI
ROCK BORING LEGEND

IN 1 SHEET — SHEET NO. 1

SCALE AS SHOWN

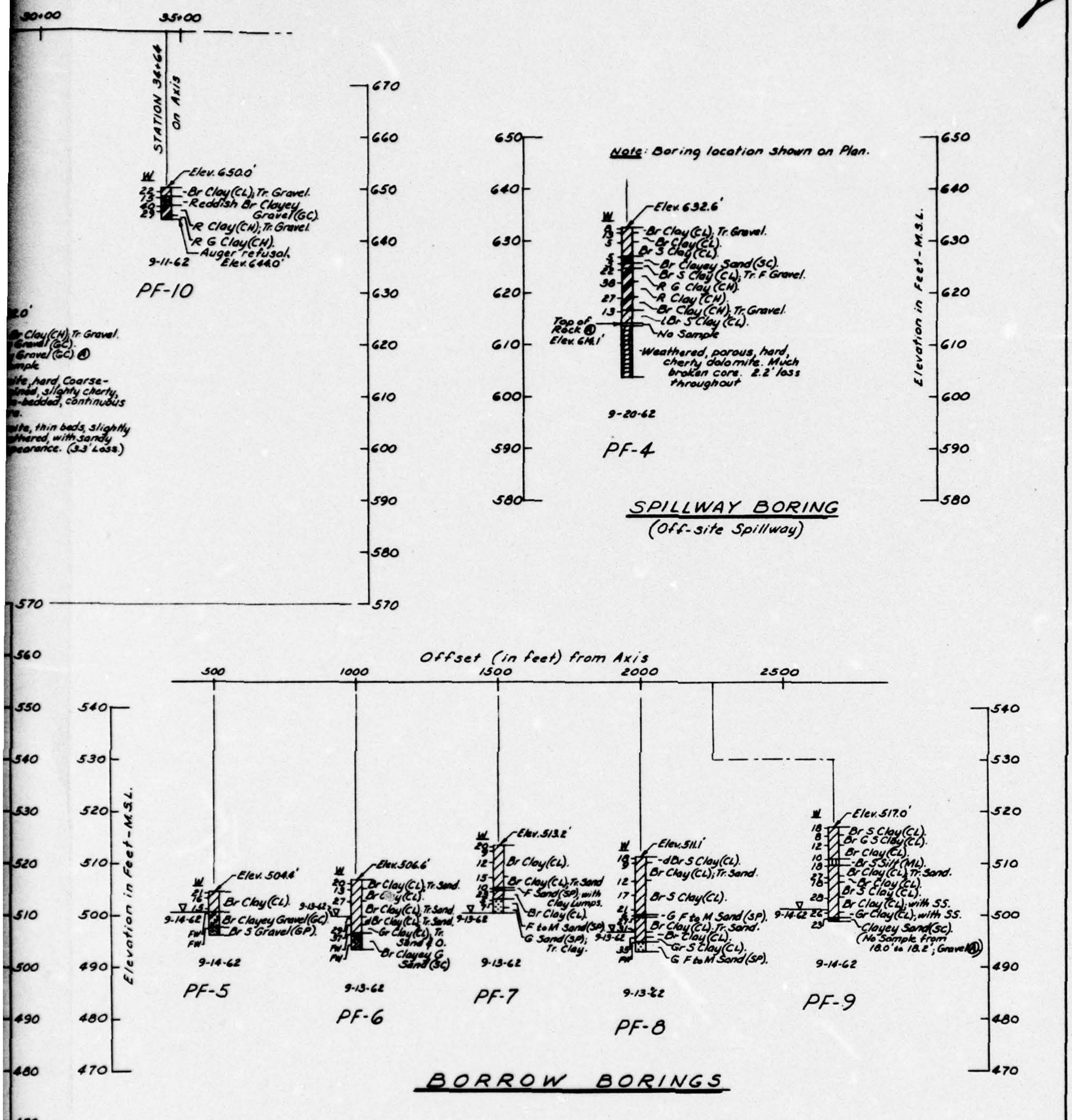
U. S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI



AXIS BORINGS (MAIN DAM)

1

2



NOTE: All core borings NX

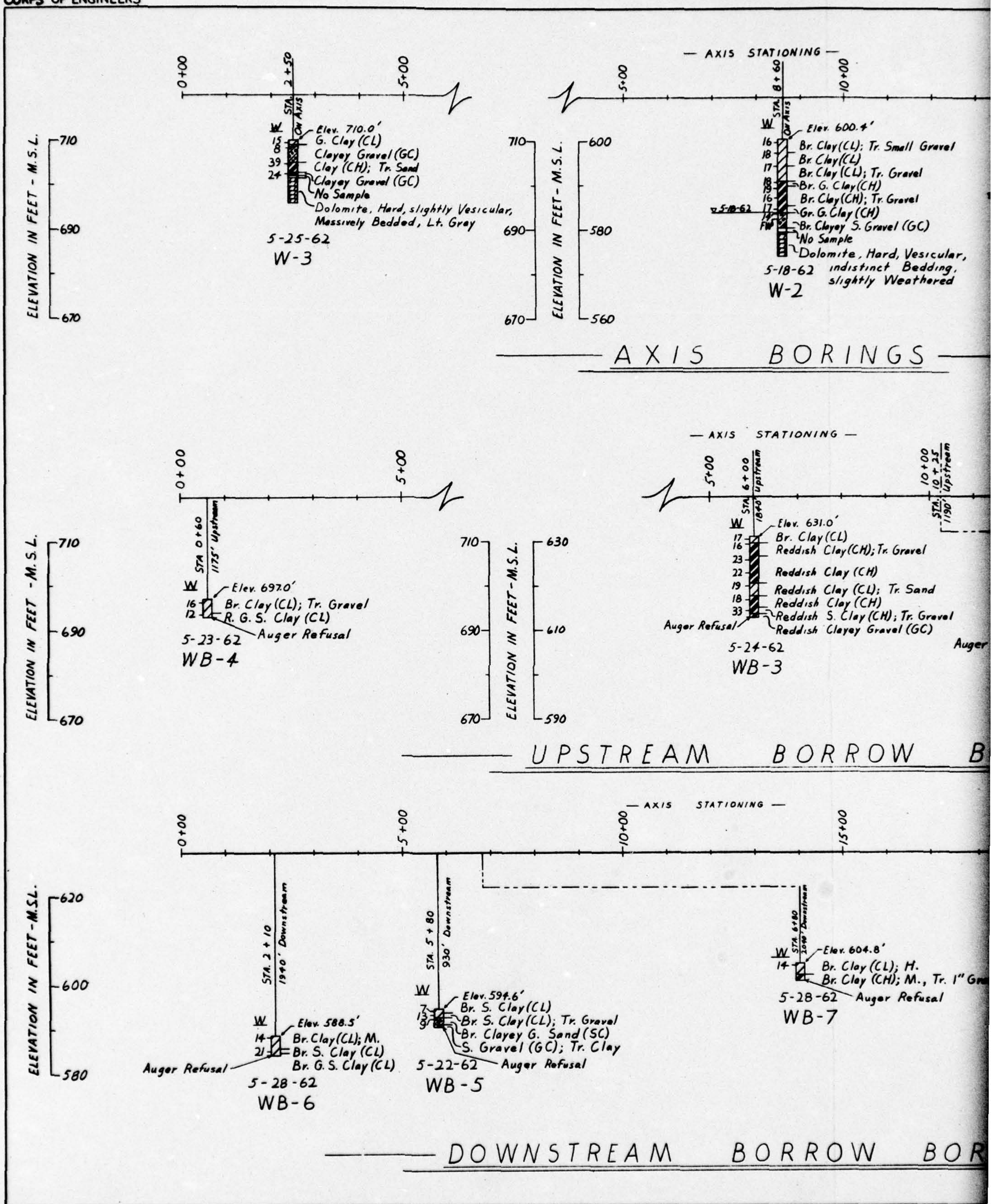
MERAMEC RIVER BASIN, MISSOURI
BIG RIVER
PINE FORD DAM
LOGS OF BORINGS

IN 1 SHEET — SHEET NO. 1

SCALE AS SHOWN

U. S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

CORPS OF ENGINEERS



U.S. ARMY

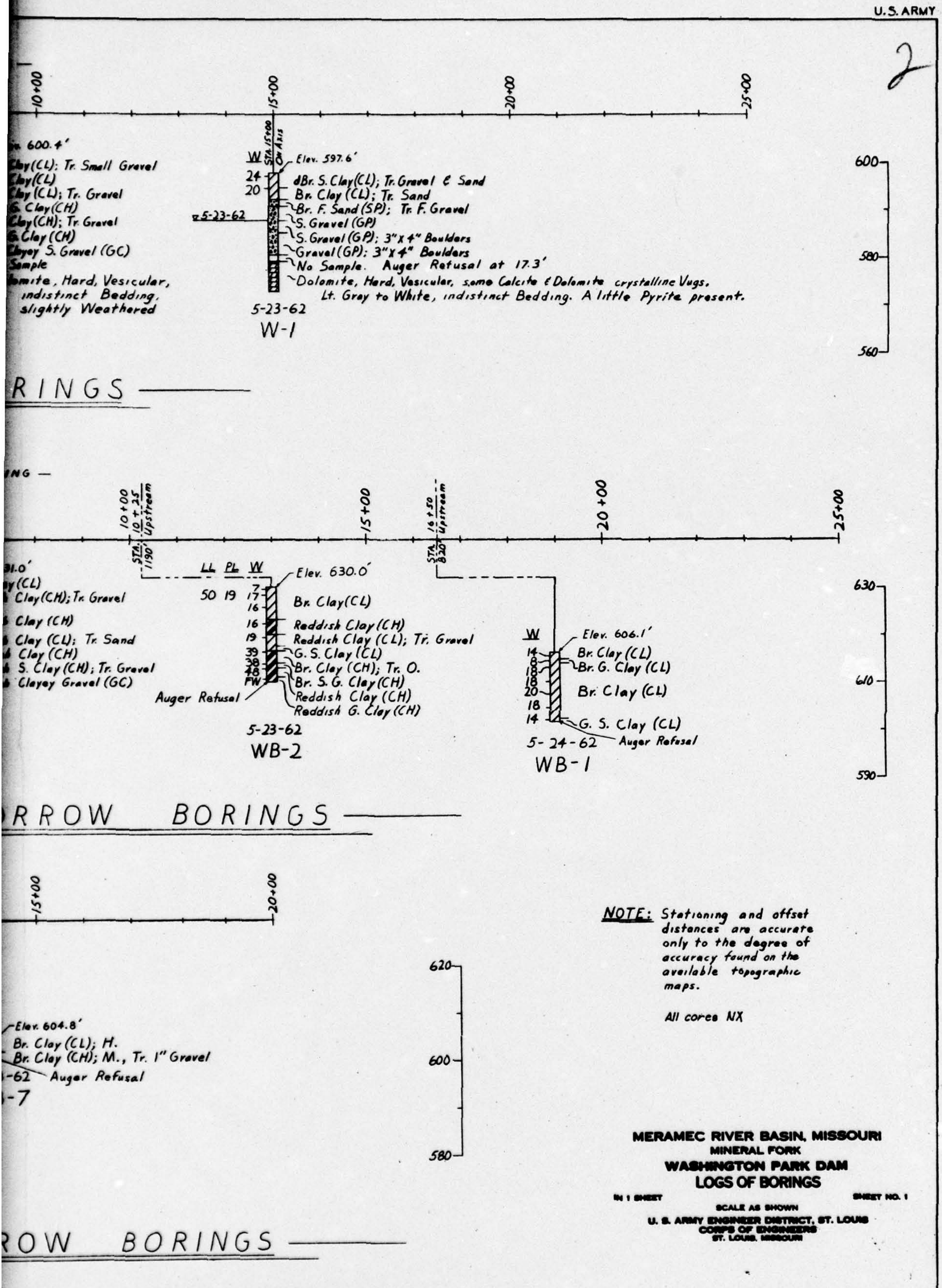
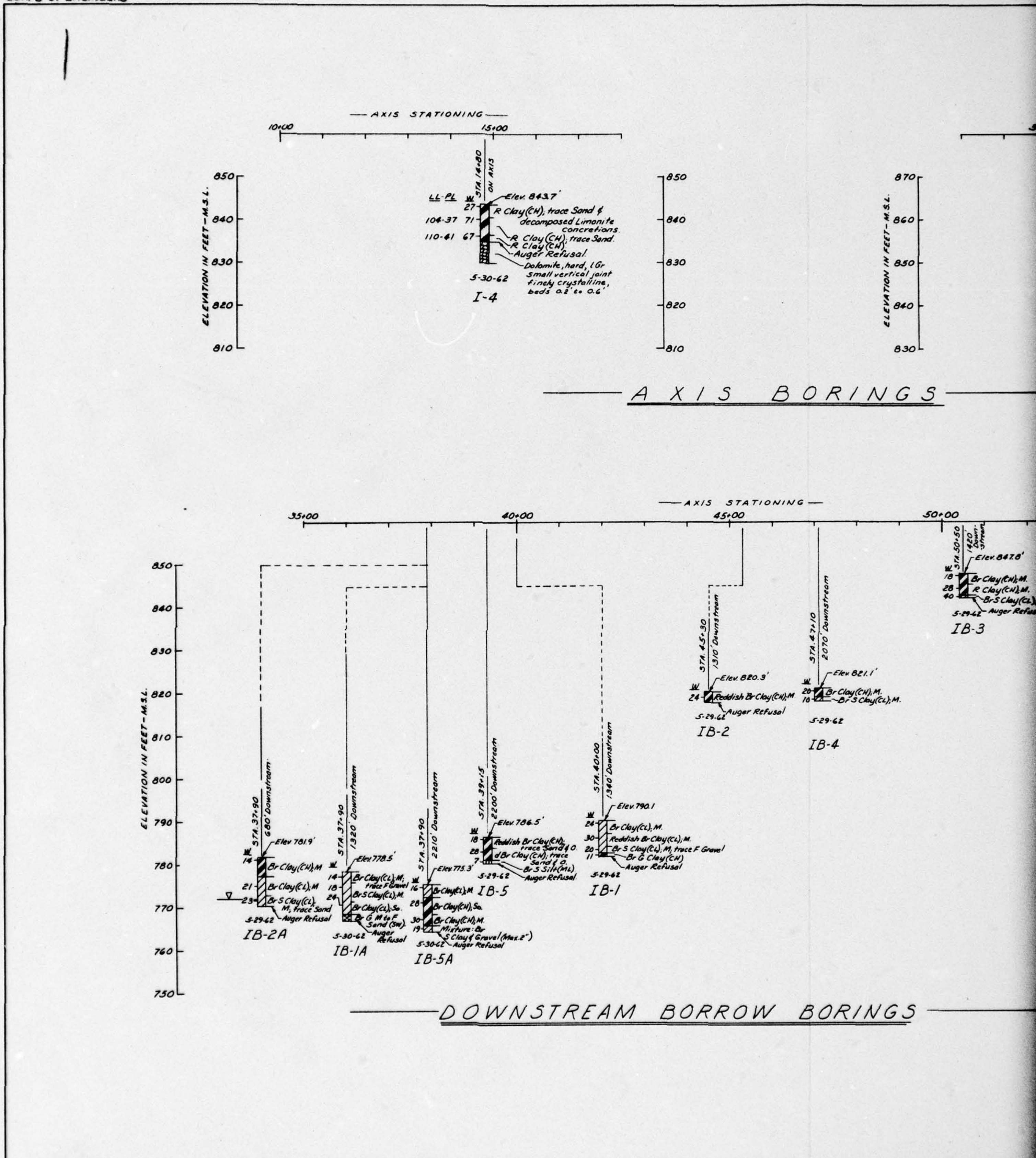


PLATE D-7

CORPS OF ENGINEERS



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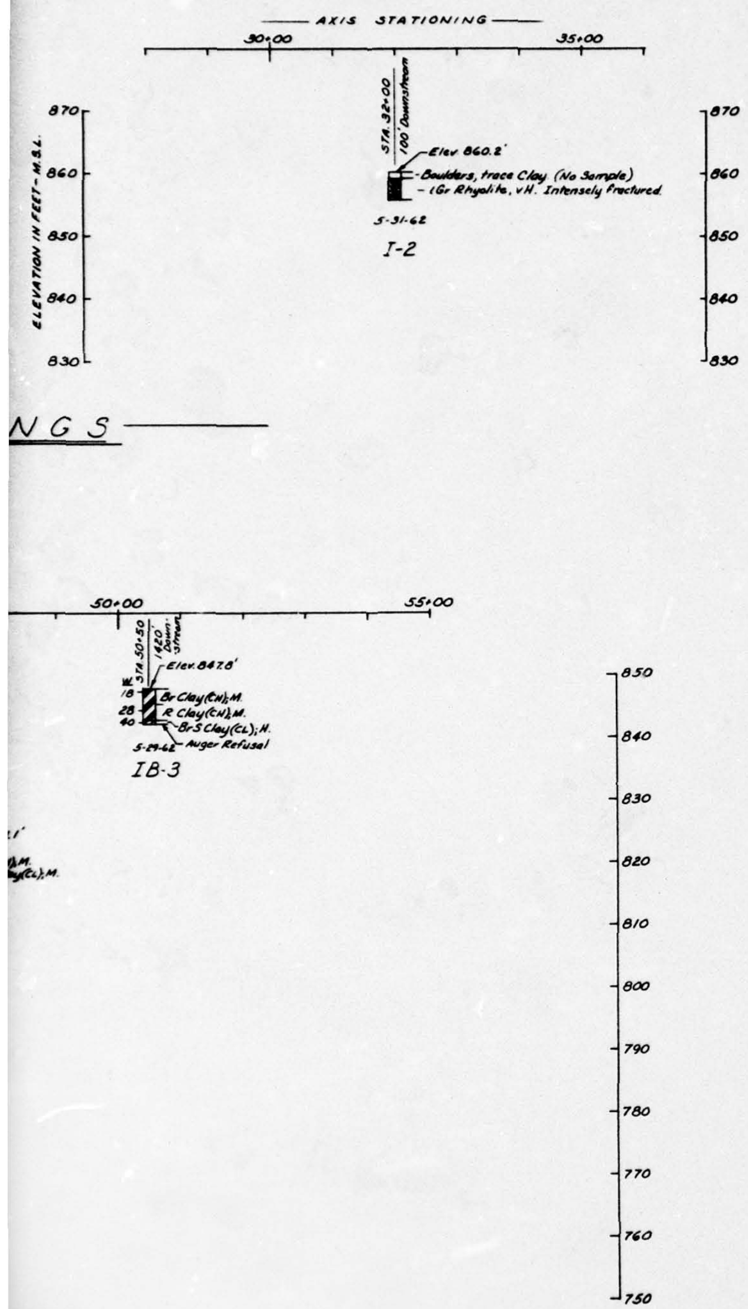


NOTE: Stationing and offset distances are accurate only to the degree of accuracy found on the available topographic maps.

All cores NX

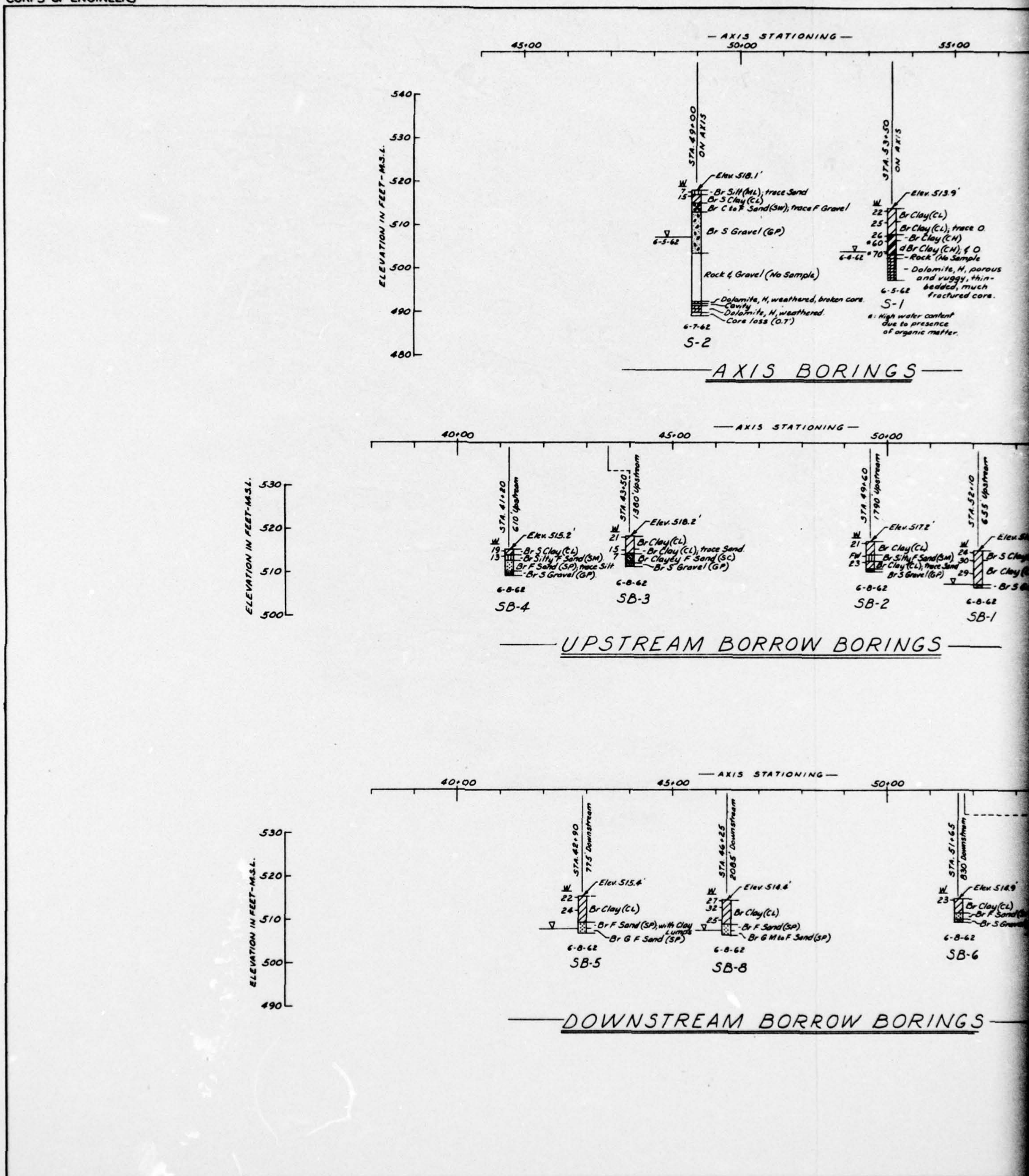
MERAMEC RIVER BASIN, MISSOURI
BIG RIVER
IRONDALE DAM
LOGS OF BORINGS

IN 1 SHEET — SHEET NO. 1

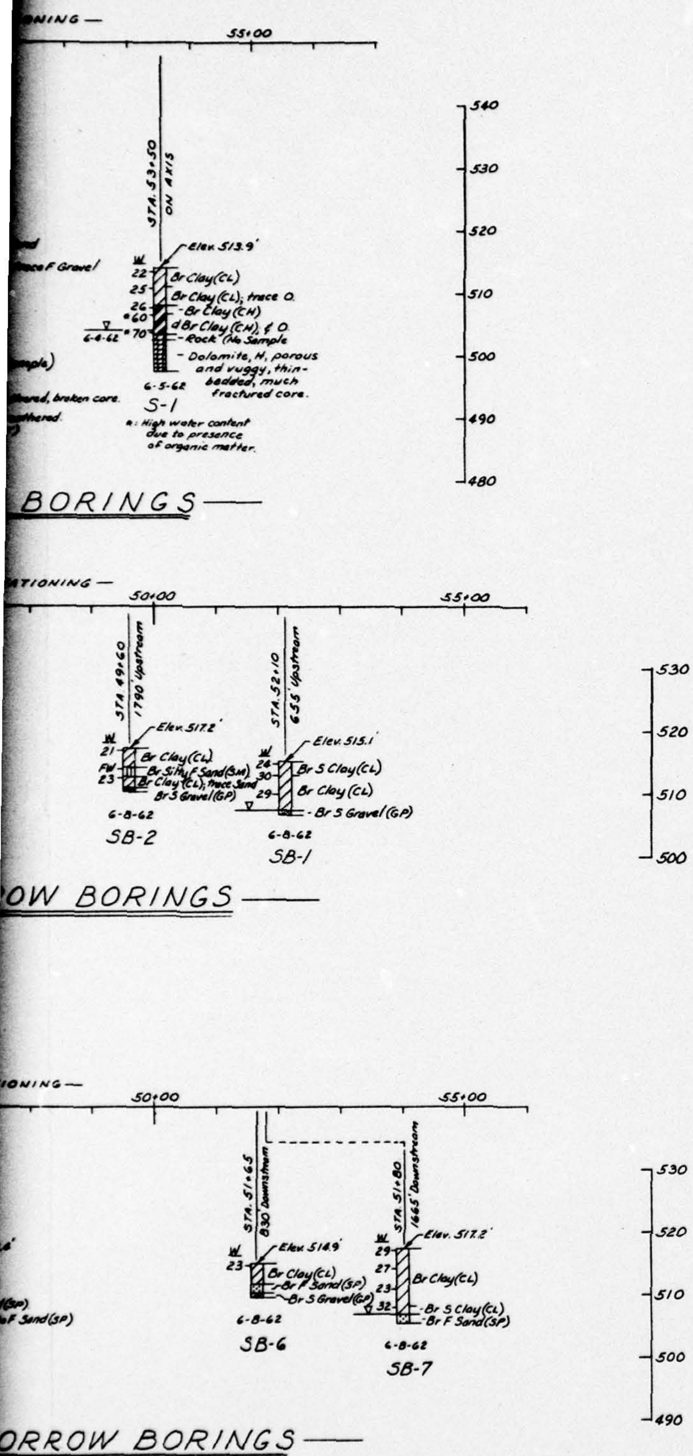
SCALE AS SHOWN

U. S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

CORPS OF ENGINEERS



2



NOTE: Stationing and offset distances are accurate only to the degree of accuracy found on the available topographic maps.

All cores NX

MERAMEC RIVER BASIN, MISSOURI
MERAMEC RIVER
VIRGINIA MINES DAM
LOGS OF BORINGS

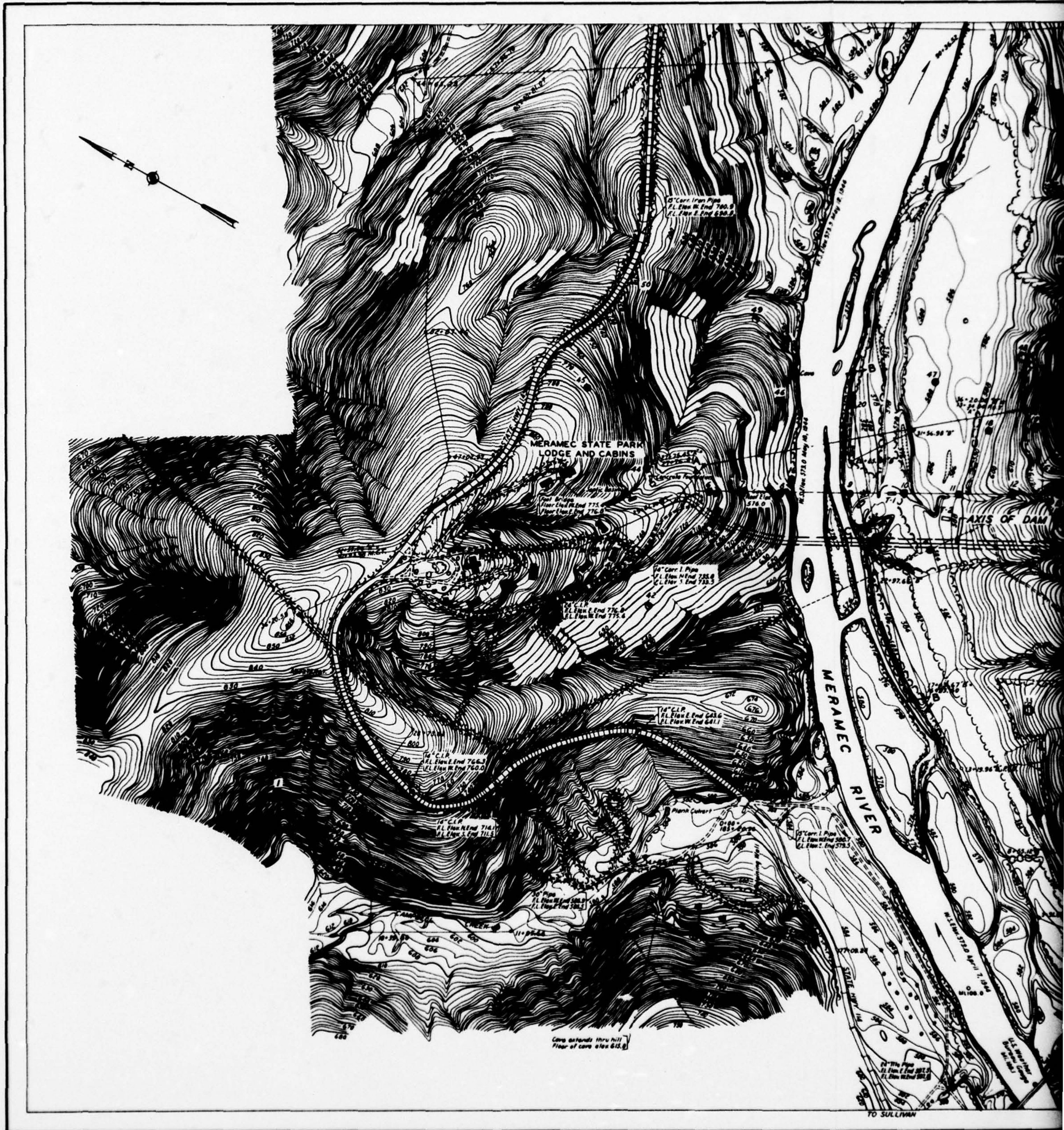
IN 1 SHEET — SHEET NO. 1

SCALE AS SHOWN

U. S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

1

CORPS OF ENGINEERS



1

2

U. S. ARMY

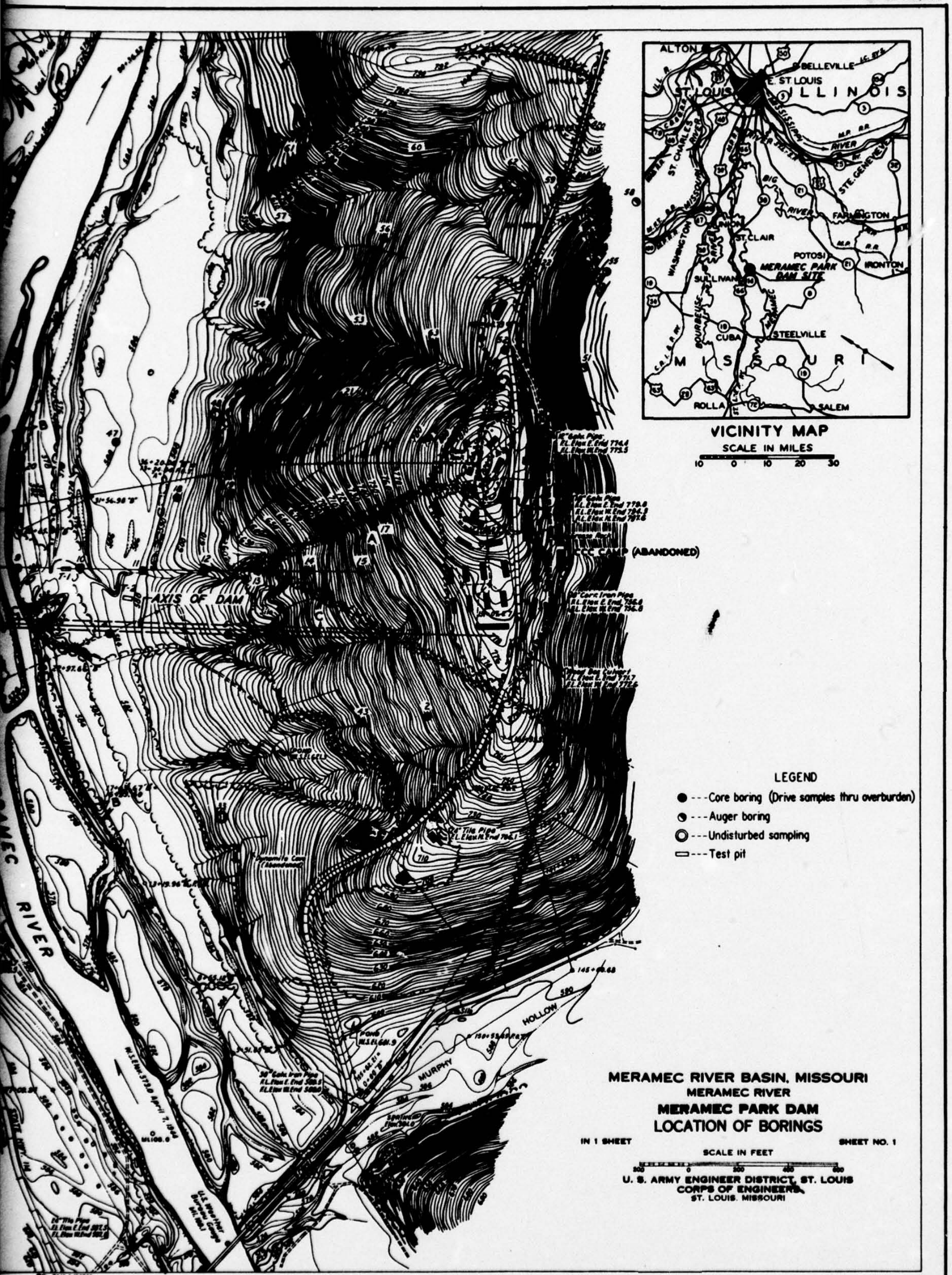
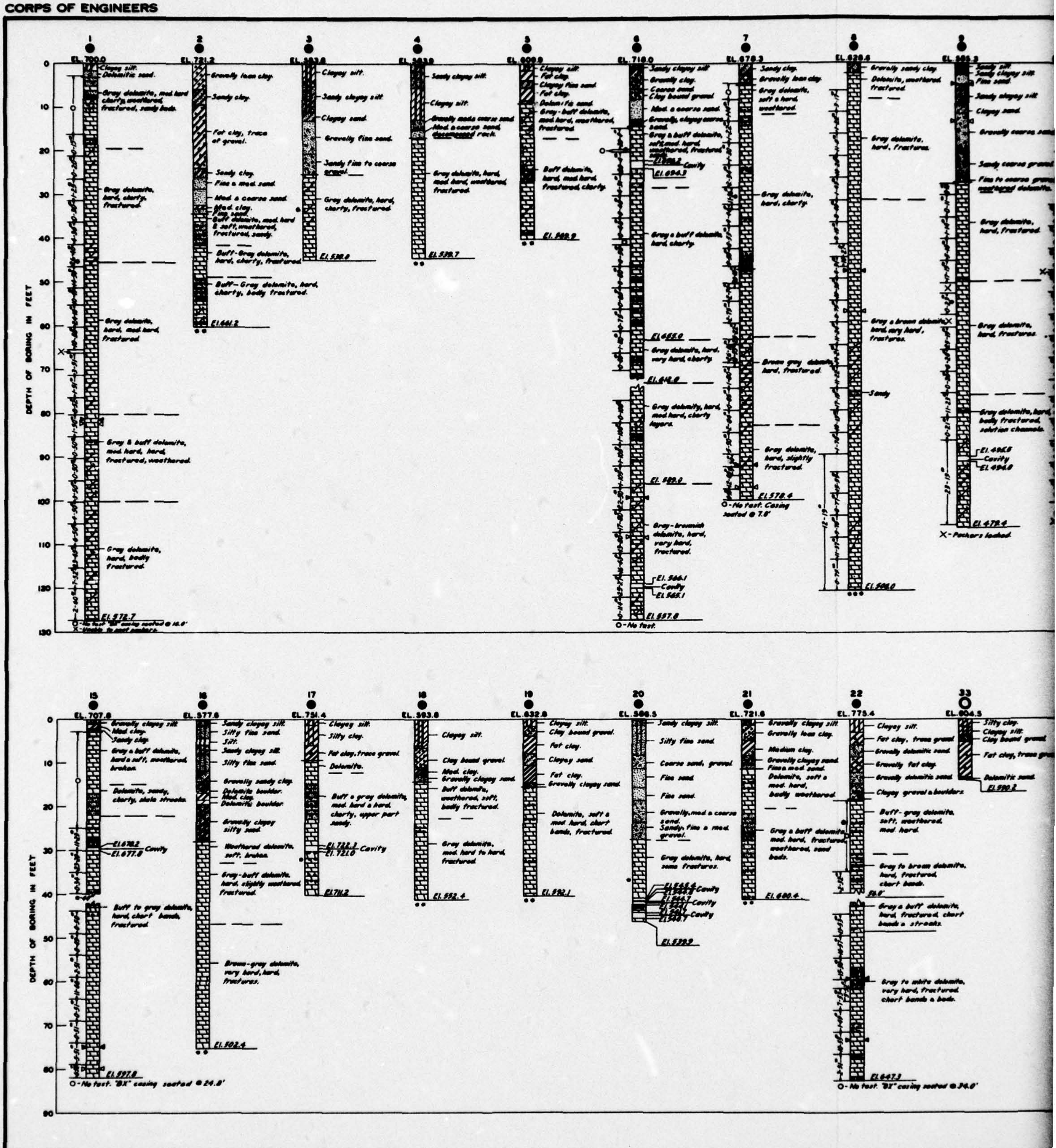
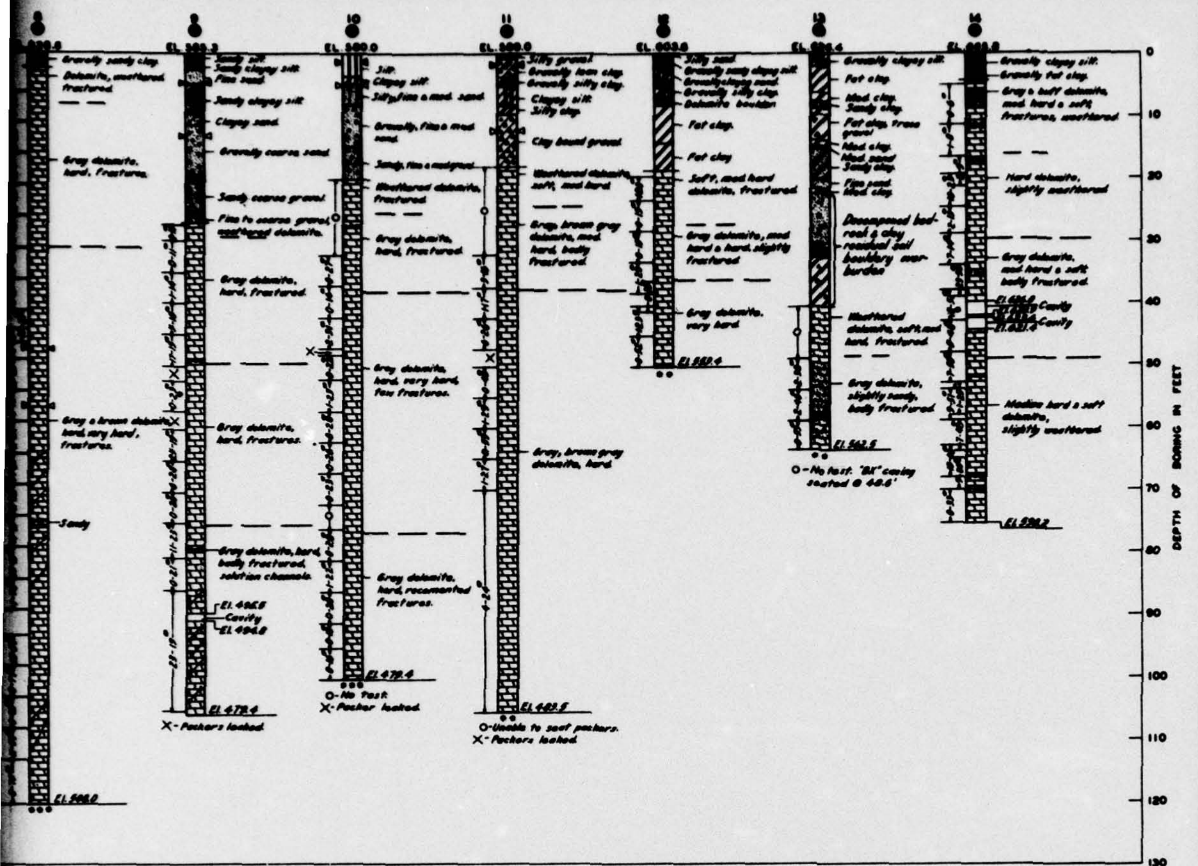
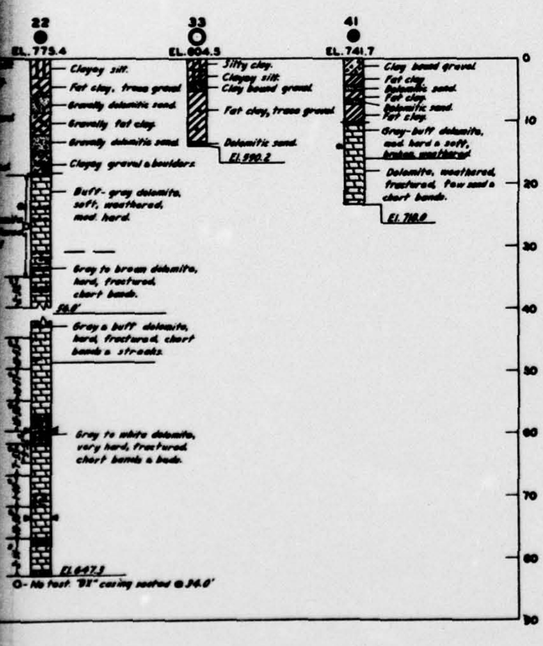


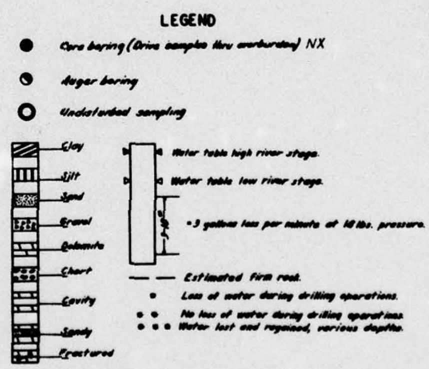
PLATE D-10

CORPS OF ENGINEERS









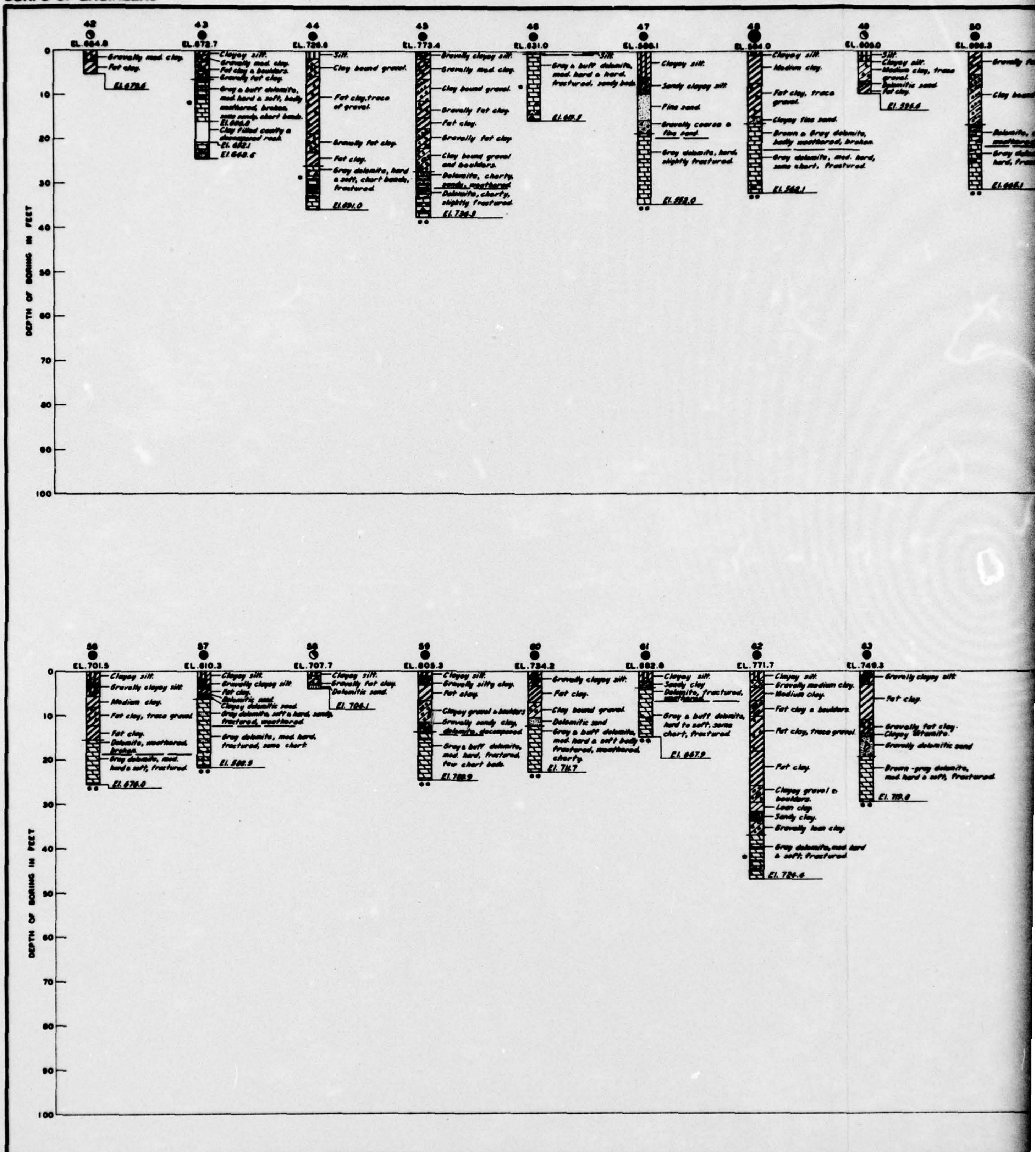
MERAMEC RIVER BASIN, MISSOURI
MERAMEC RIVER
MERAMEC PARK DAM
LOGS OF BORINGS

IN 2 SHEETS — SHEET NO. 1

SCALE AS SHOWN

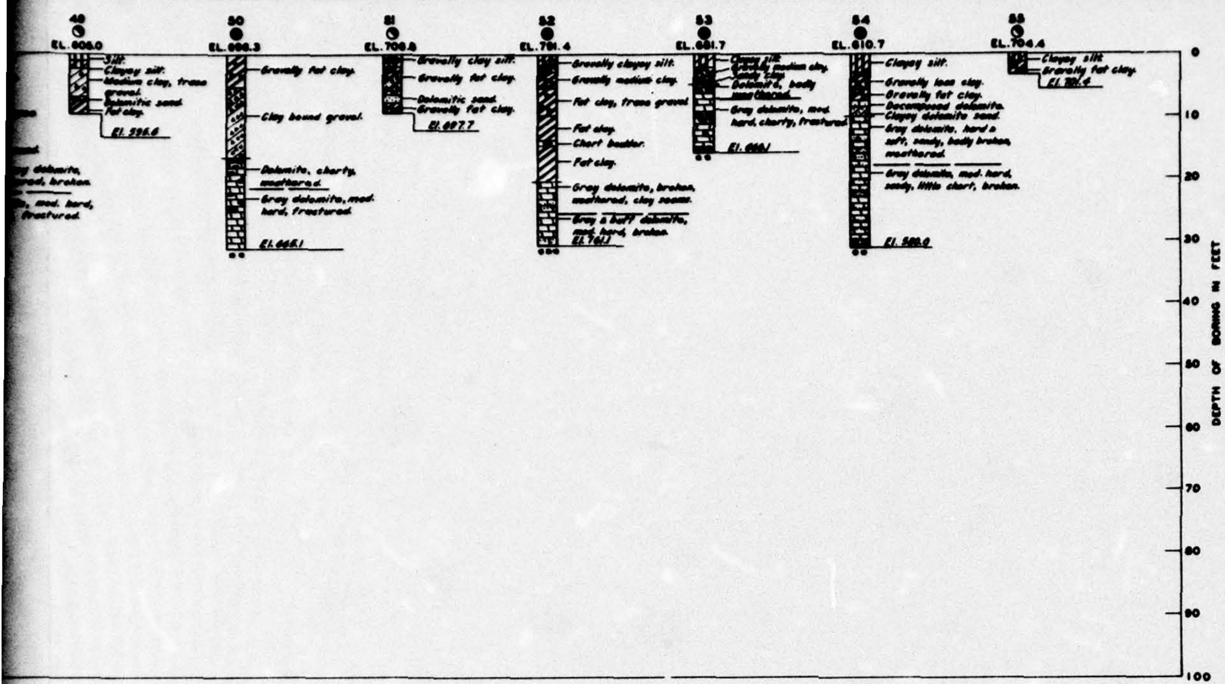
U. S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

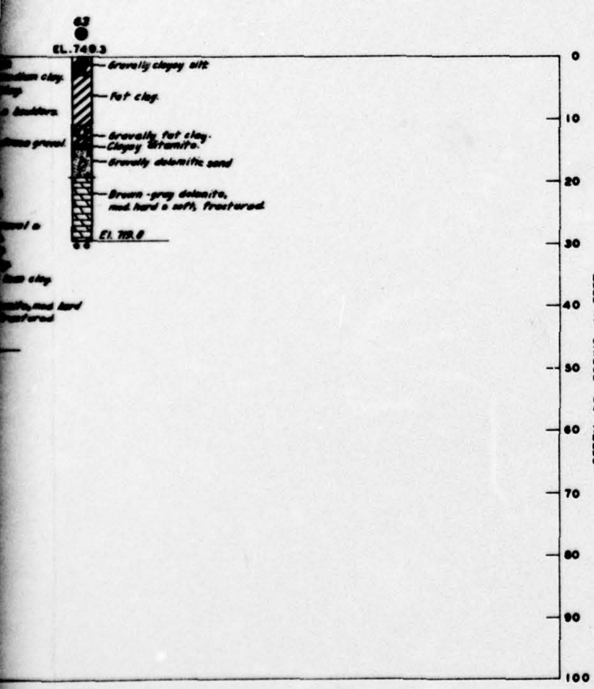
CORPS OF ENGINEERS



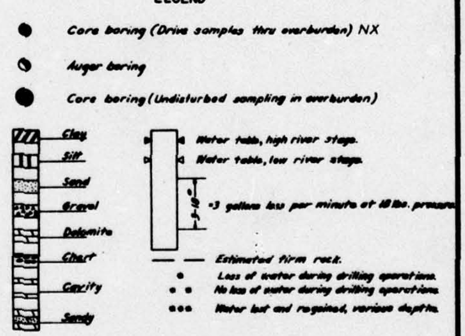
2

U. S. ARMY





LEGEND

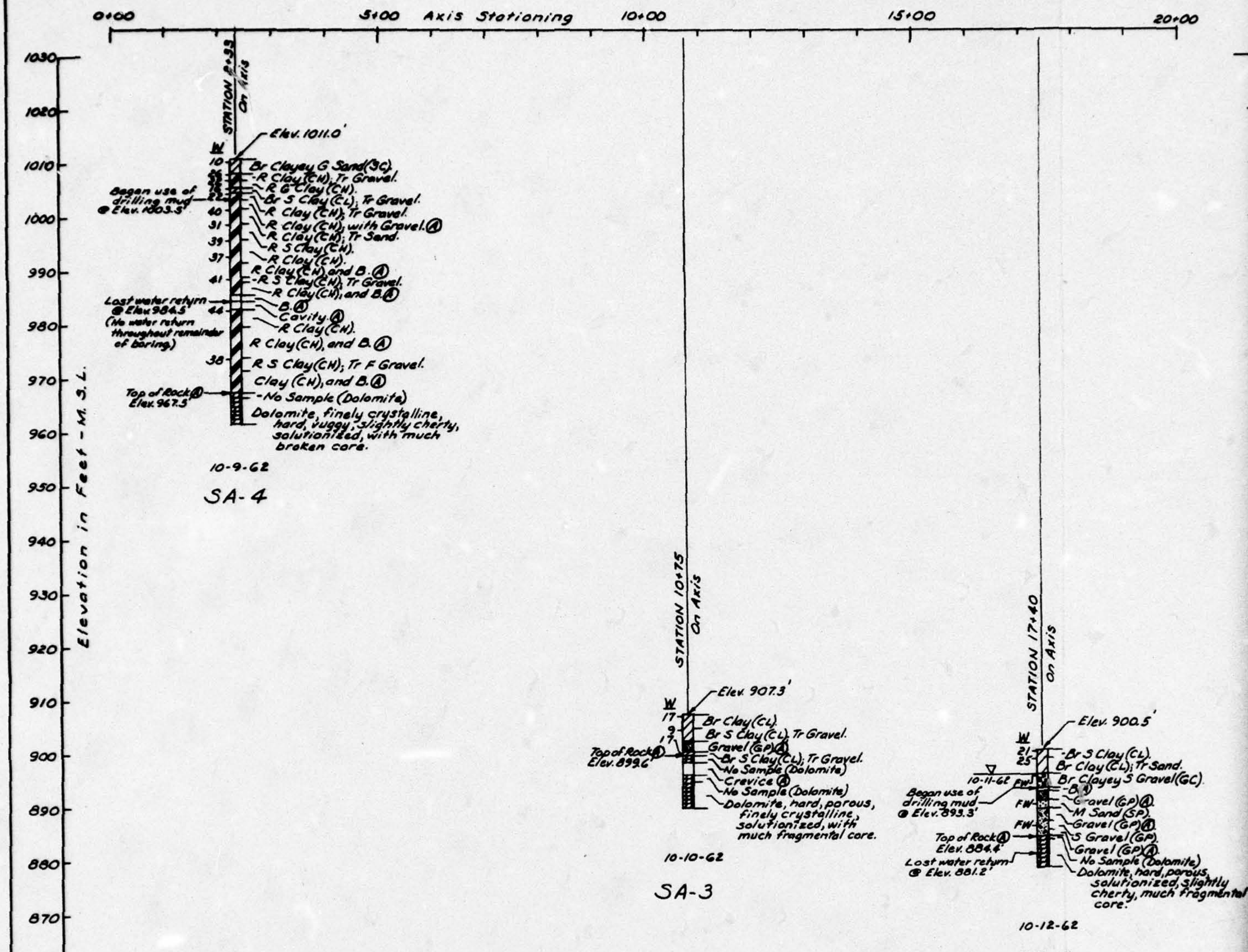


MERAMEC RIVER BASIN, MISSOURI
MERAMEC RIVER
MERAMEC PARK DAM
LOGS OF BORINGS

IN 2 SHEETS SHEET NO. 2

SCALE AS SHOWN

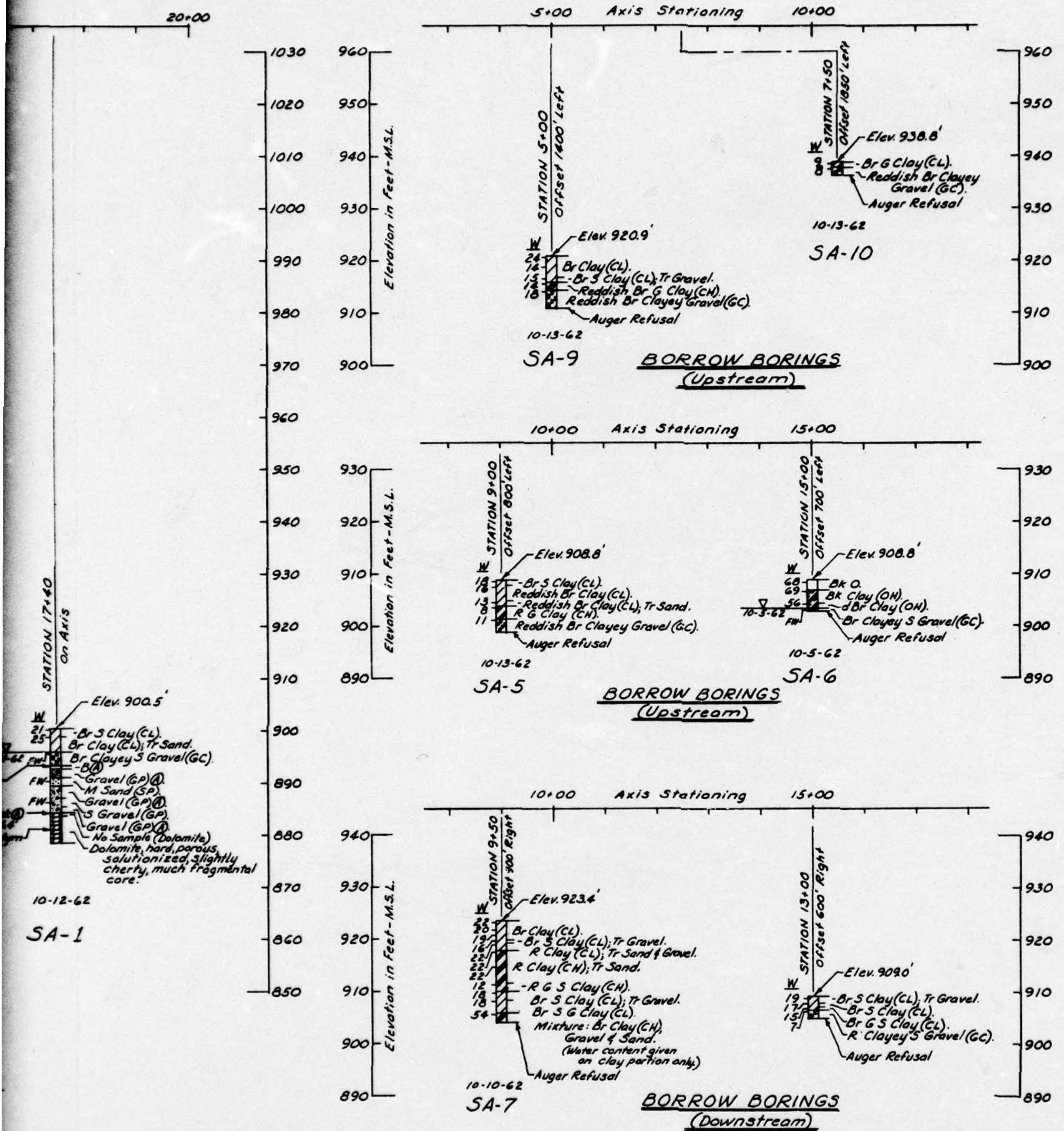
U. S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS MISSOURI



AXIS BORINGS

2

U.S. ARMY



NOTE: All core borings NX

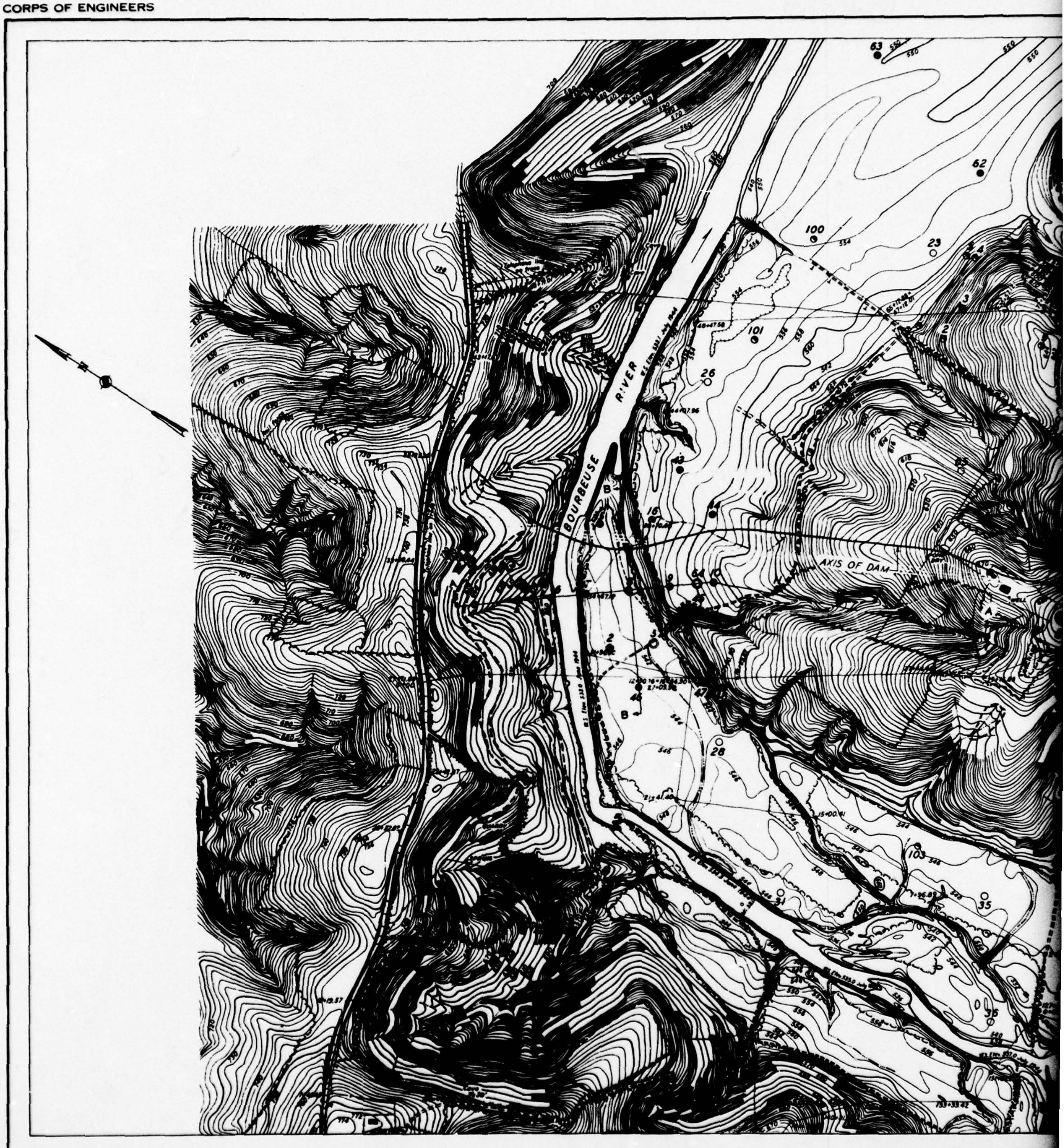
MERAMEC RIVER BASIN, MISSOURI
MERAMEC RIVER
SALEM DAM
LOGS OF BORINGS

IN 1 SHEET — SHEET NO. 1

SCALE AS SHOWN

U. S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

CORPS OF ENGINEERS



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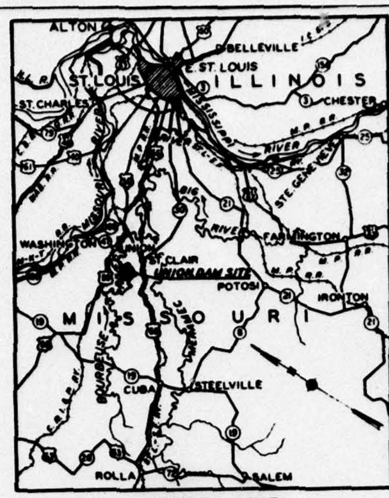


VICINITY MAP

SCALE IN MILES

10 0 10 20 30

LEGEND

- Core Boring (Drive Samples thru Overburden)
- Drive Boring
- Auger Boring
- Undisturbed Sampling
- Rock outcrop

MERAMEC RIVER BASIN, MISSOURI

BOURBEUSE RIVER

UNION DAM

LOCATION OF BORINGS

IN 1 SHEET SHEET NO. 1

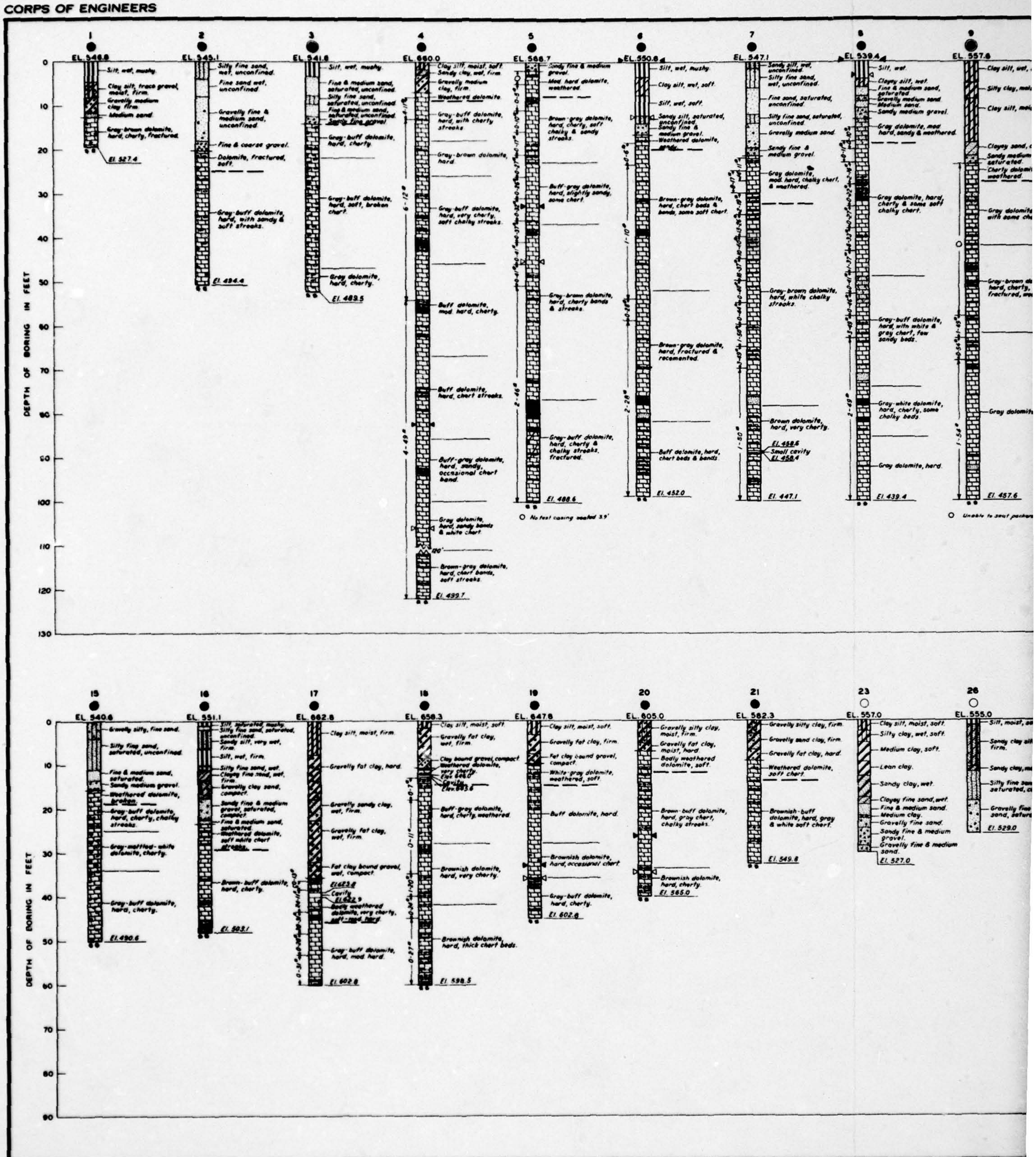
SCALE IN FEET

U. S. ARMY ENGINEER DISTRICT, ST. LOUIS

CORPS OF ENGINEERS

ST. LOUIS MISSOURI

CORPS OF ENGINEERS



AD-A036 827 ARMY ENGINEER DISTRICT ST LOUIS MO F/G 8/6
MERAMEC RIVER, MISSOURI COMPREHENSIVE BASIN STUDY. VOLUME IV. A--ETC(U)
JAN 64

UNCLASSIFIED NL

3 OF 3
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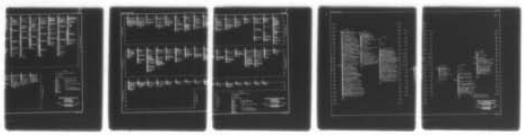
A036827



END
DATE
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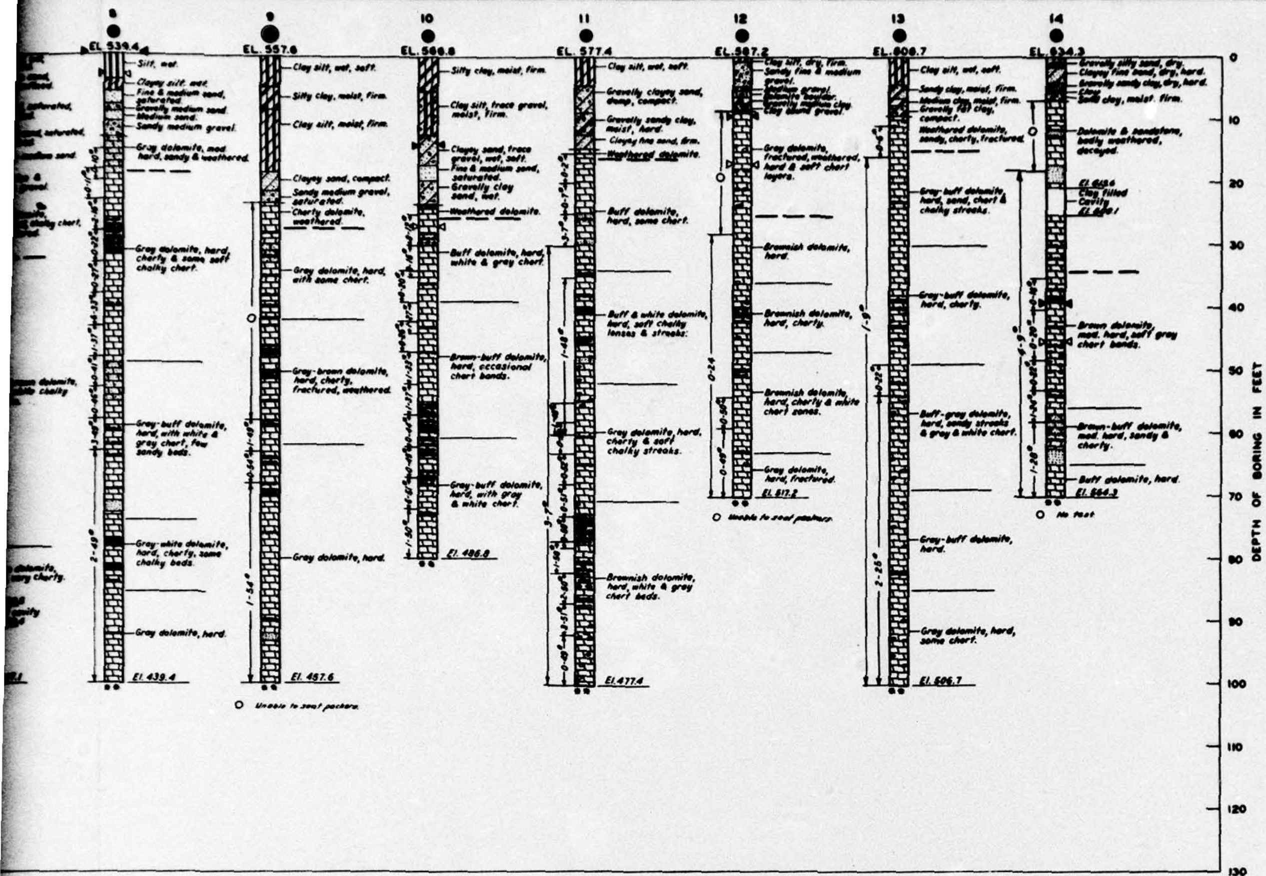
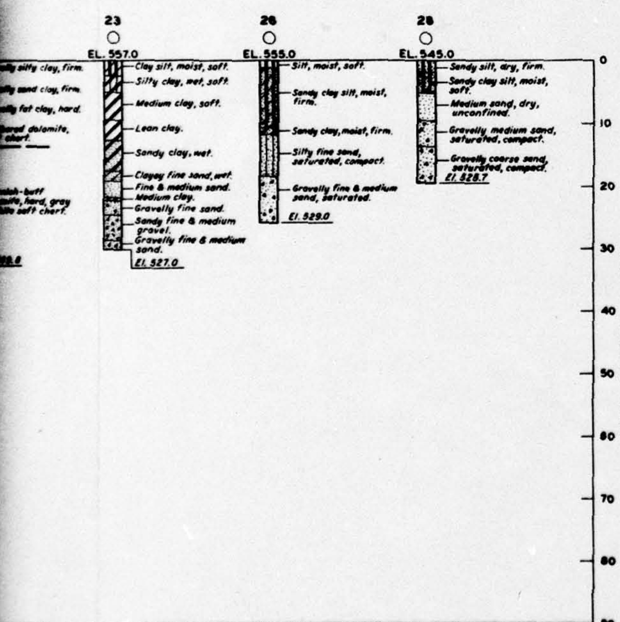
4-77





LEGEND

- ● Core boring (Drive samples thru overburden) NX
- ○ Drive boring
- ◔ Auger boring
- ⬤ Core boring (Undisturbed sampling in overburden)

Clay
Silt
Sand
Gravel
Dolomite
Chert
Cavity
Sandy
Sandstone

Water table high river stage.
Water table low river stage.
3-10 = 3 gallons loss per minute at 10 lbs. pressure.
Estimated firm rock.
• Loss of water during drilling operation.
•• No loss of water during drilling operations.

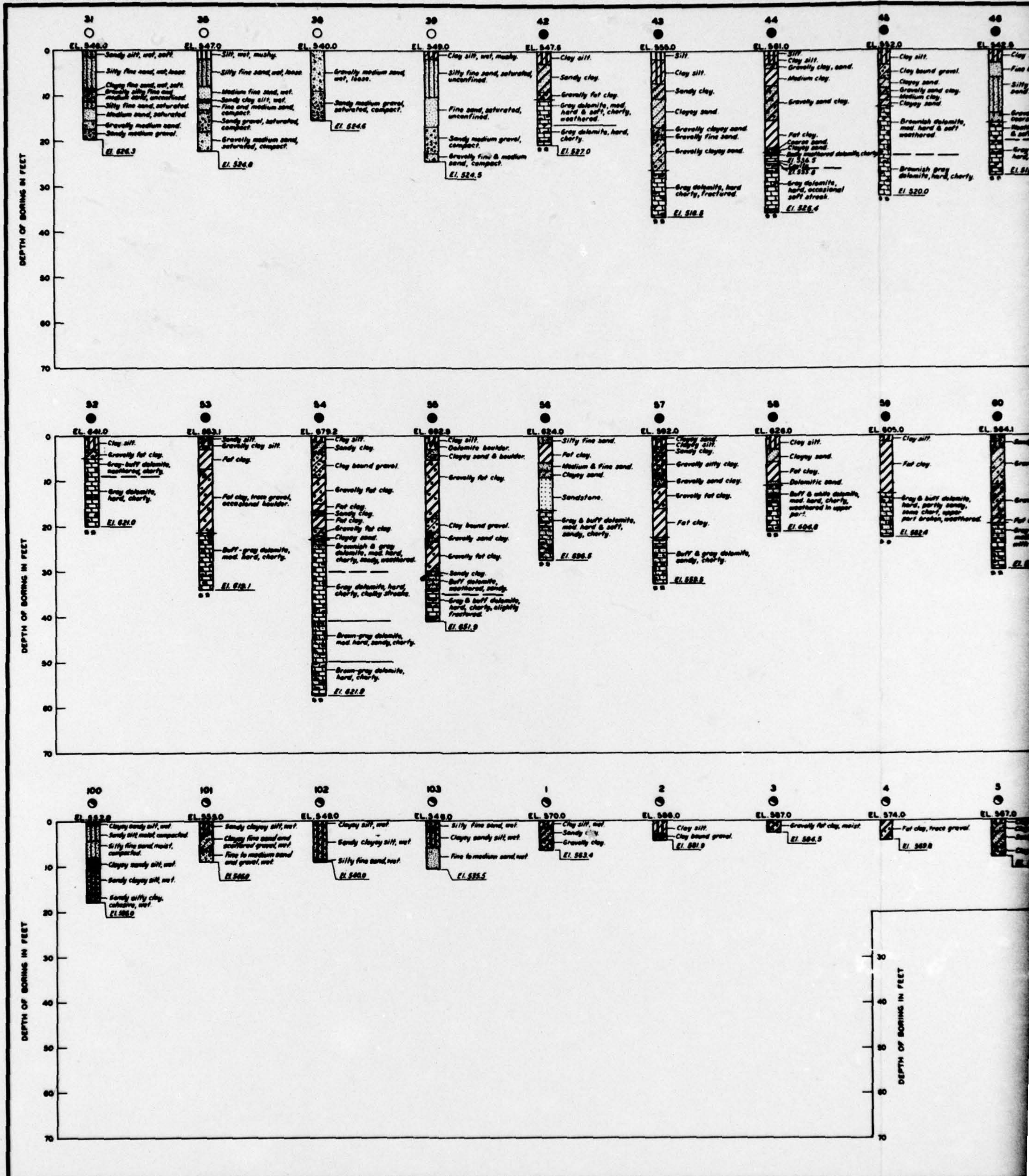
MERAMEC RIVER BASIN, MISSOURI
BOURBEUSE RIVER
UNION DAM
LOGS OF BORINGS

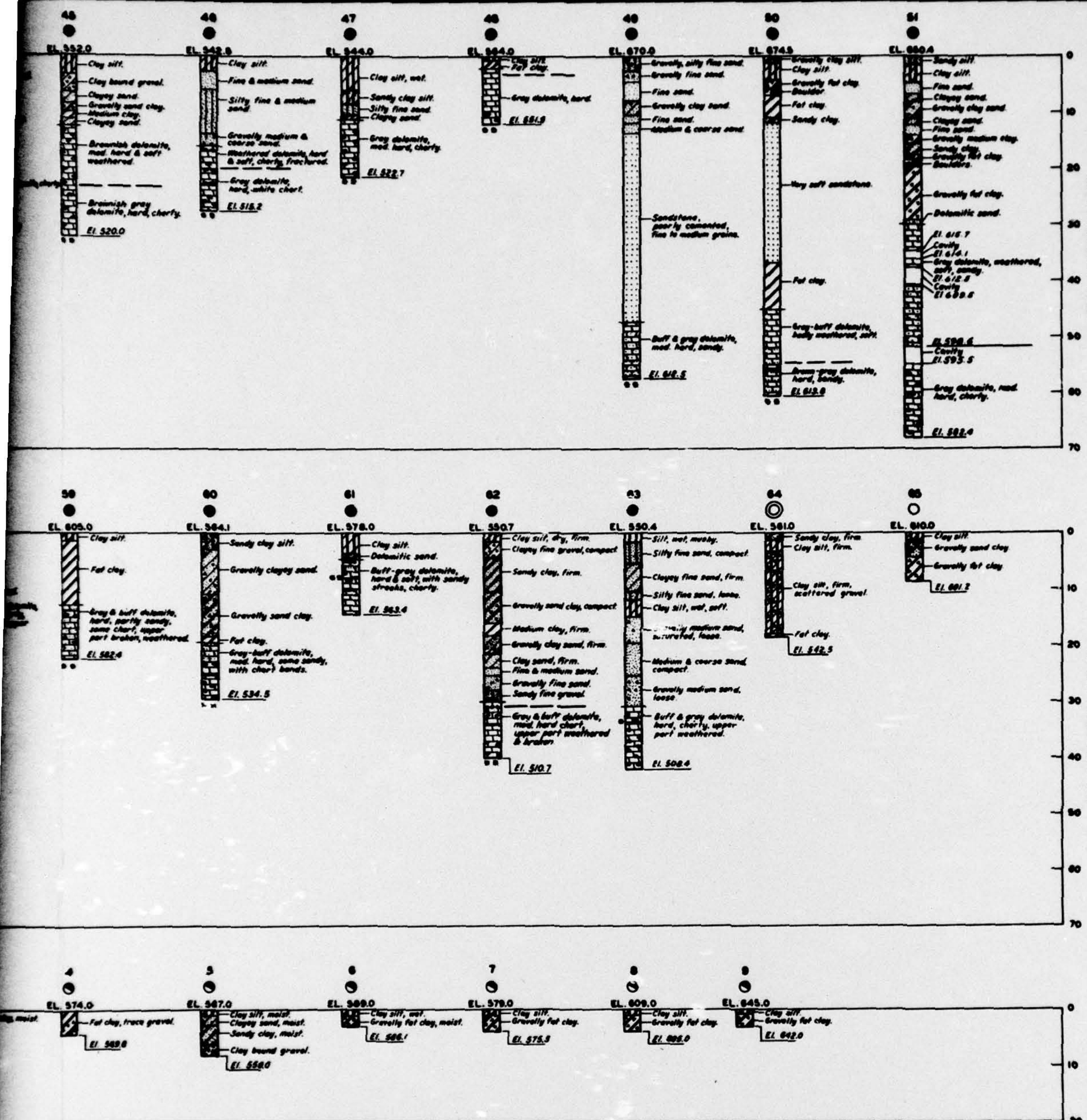
IN 2 SHEETS — SHEET NO. 1

SCALE AS SHOWN

U. S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

CORPS OF ENGINEERS





LEGEND

- Core boring (Drive samples thru overburden) NX
- Drive boring
- Auger boring
- Undisturbed sampling

Clay
Silt
Sand
Gravel
Dolomite
Chert
Cavity
Sandy
Sandstone

Water table high river stage.
Water table low river stage.
+3 gallons loss per minute at 10 lbs. pressure.
Estimated firm rock.
Loss of water during drilling operations.
No loss of water during drilling operations.

DEPTH OF BORING IN FEET

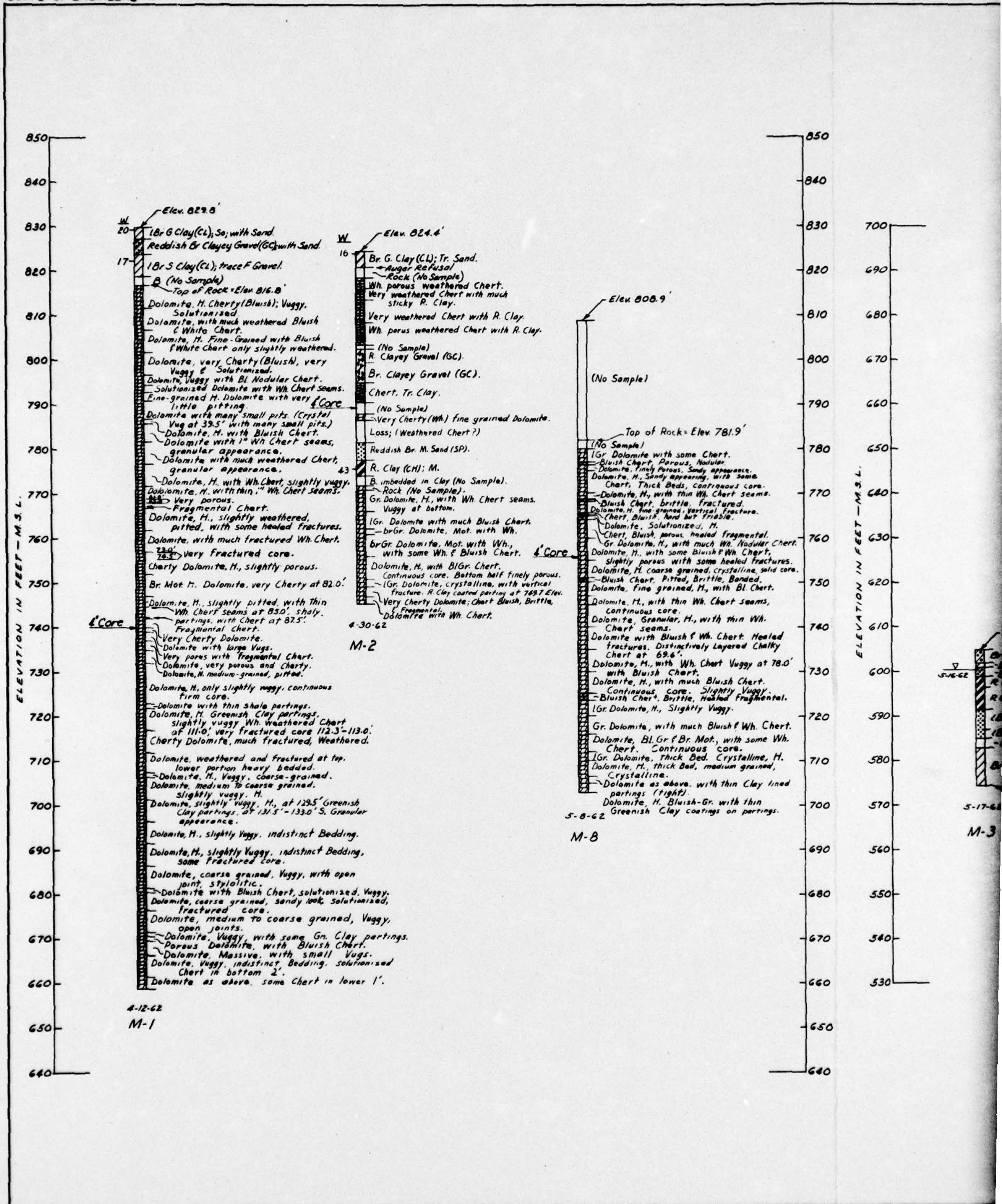
MERAMEC RIVER BASIN, MISSOURI
BOURBEUSE RIVER
UNION DAM
LOGS OF BORINGS

IN 2 SHEETS — SHEET NO. 2

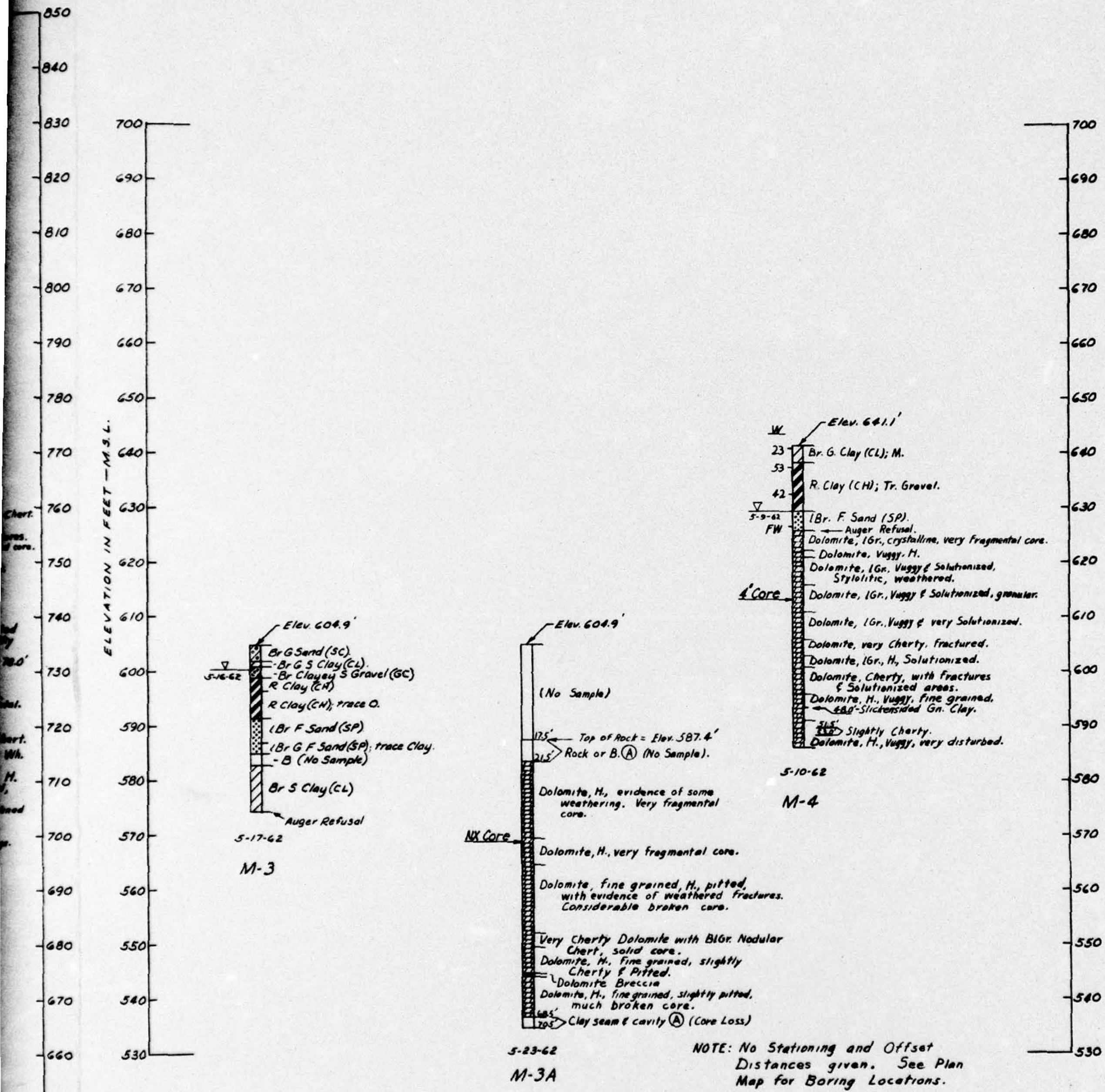
SCALE AS SHOWN

U. S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

CORPS OF ENGINEERS



2



NOTE: No Stationing and Offset Distances given. See Plan Map for Boring Locations.

MERAMEC RIVER BASIN, MISSOURI
MERAMEC RIVER
MERAMEC PARK HILLTOP DAM
LOGS OF BORINGS

IN 1 SHEET — SHEET NO. 1

SCALE AS SHOWN

U. S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI